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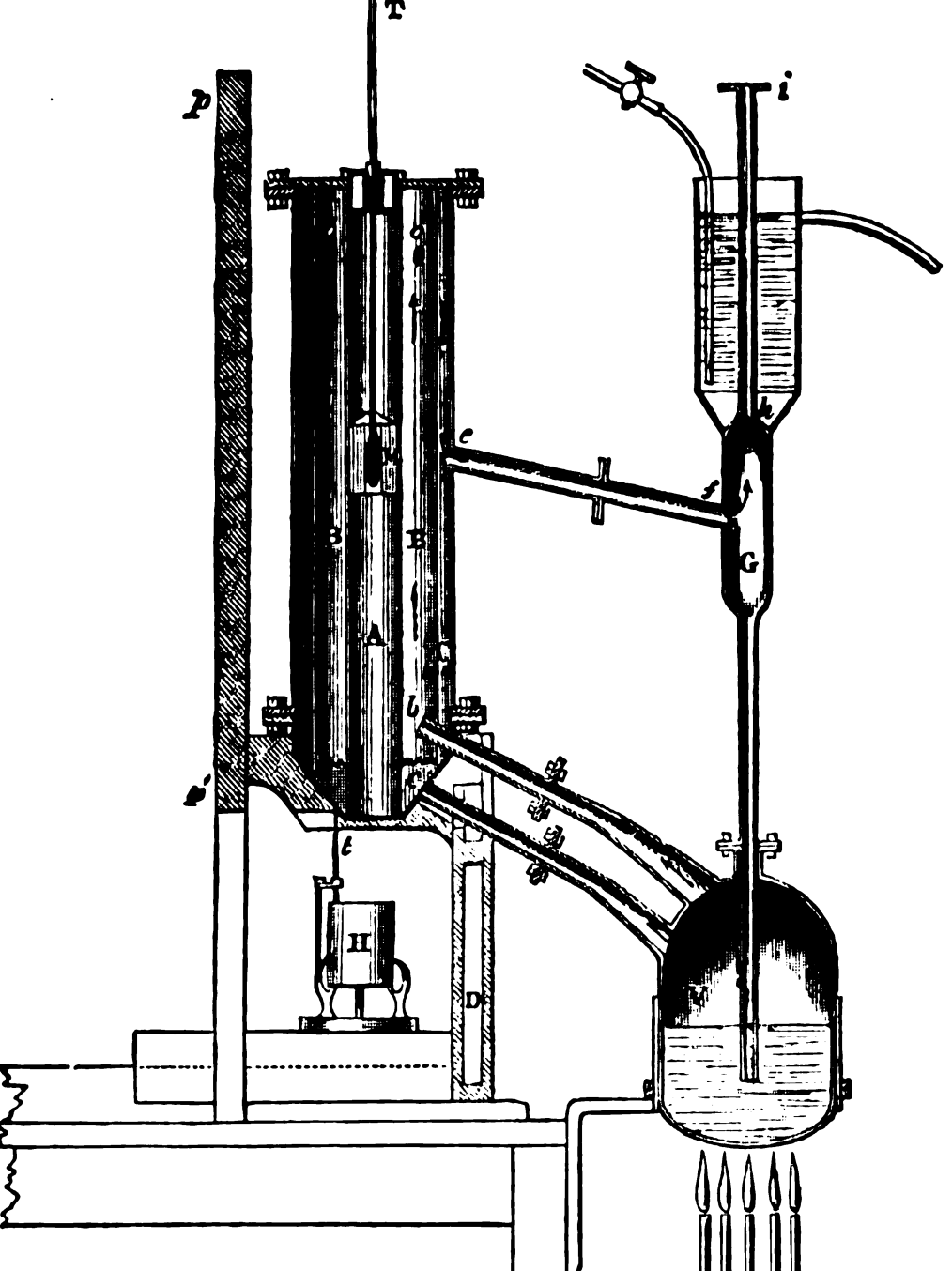
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A Dictionary of chemistry and the allied branches of other sciences ...

Henry Watts

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VOL. III.

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A DICTIONARY

OF

CHEMISTRY

AND THE

ALLIED BRANCHES OF OTHER SCIENCES.

BY

HENRY WATTS, B.A., F.R.S., F.C.S.

EDITOR OF

'THE JOURNAL OF THE CHEMICAL SOCIETY.'

ASSISTED BY EMINENT CONTRIBUTORS.

VOL. III.

HÆMAPHEIN—MYSORIN.

NEW EDITION.

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H.

HÆMAPHEIN. *Blood-brown.* (Simon, *Medicin. Chem.* i. 328; Handw. d. Chem. 2te. Aufl. ii. [2] 157.) A brown substance, probably a product of the decomposition of hæmatin, obtained from blood by the following process:—Dried blood is repeatedly exhausted with boiling water, warm ether, and lastly with alcohol containing sulphuric acid, and the latter solution, after supersaturation with ammonia, is evaporated to dryness. The residue is exhausted with alcoholic ammonia, the solution is again evaporated to dryness, and the residue is exhausted with ether, and then repeatedly with water, in which the hæmaphein dissolves. To free it from still admixed hæmatin, it is dried, dissolved in boiling alcohol, separated again by evaporation, then dissolved in cold alcohol, and the alcohol is evaporated. The product thus obtained is a brown mass difficult to pulverise, soluble with brown-red colour in cold alcohol, less soluble in water and in ether. It does not melt when heated, but burns with a bright flame, without leaving any ash. The solution in dilute alcohol forms brown precipitates with lead, copper, mercurous and silver salts. Sanson obtained a body of similar colour to the above by treating blood successively with alcohol and water.

HÆMATEIN. $C^{16}H^{12}O^4$, or $C^{16}H^{10}O^3$. (Erdmann, Ann. Ch. Pharm. xliv. 294.—Hesse, *ibid.* cix. 232.)—A substance produced from hæmatoxylin by abstraction of 2 at. hydrogen, a change which takes place by the action of oxygen under the influence of alkalis. The best mode of preparing it is to sprinkle about 20 grms. of hæmatoxylin in a basin with sufficient ammonia to dissolve it, stirring continually, and warming the liquid gently as long as the hæmatoxylin remains in excess. It must now be exposed to the air, and ammonia added from time to time by small quantities, so that the liquid may always smell of it, care being however taken not to add too much ammonia, as it would cause decomposition. The liquid after a little while assumes a dark red colour, appearing almost black when viewed in a stratum of moderate depth. It then contains hæmateate of ammonium, and on being slightly supersaturated with acetic acid, deposits hæmatein in the form of a bulky brown-red mass, like ferric hydrate, which by drying acquires a deep green colour and metallic lustre: its powder in thin layers, exhibits a red colour.

Hæmatein dissolves slowly in cold, more readily in boiling water. On quickly evaporating a solution prepared at the boiling heat, it becomes covered with shining green scales, which sink to the bottom and are gradually replaced by others. Sometimes also the solution solidifies in a gelatinous mass, which yields micaceous laminæ when suspended in water. Hæmatein likewise dissolves in alcohol and very sparingly in ether. It dissolves with red-brown colour in the mineral acids, less easily in acetic acid. Sulphydric acid decolorises it, but does not convert it into hæmatoxylin. It is carbonised by heat.

Hæmatein unites readily with bases. *Potash* dissolves it, forming a blue solution, which turns brown on exposure to the air. *Ammonia* dissolves it with a fine purple colour, which likewise turns brown in the air.

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The last-mentioned solution contains hæmateate of ammonium, which is likewise formed when a solution of hæmatoxylin in ammonia is exposed to the air. The salt deposited by gradual evaporation is a dark violet, granular powder, which, when examined by the microscope, appears to be composed of transparent, violet, four-sided prisms. It contains, according to Erdmann's analysis, 56·26 per cent. C, 5·17 H, and 6·72 N (mean), whence Gerhardt (*Traité*, iv. 303) deduced the formula $C^{16}H^{16}(NH^4)^2O^6$ (57·5 C, 5·4 H, and 8·3 N). Hesse, by leaving the solution to stand for two or three days in a cool place, obtained crystals in which he found 51·87 C, 5·78 H, and 3·55 N (mean), agreeing nearly with the formula $C^{16}H^9(NH^4)O^5.4H^2O$, which requires 51·75 C, 5·66 H, and 3·77 N. Hæmateate of ammonium dissolves readily in water and alcohol. The alcoholic solution is red-brown, but becomes purple on addition of water. The salt gives off water and ammonia at 100° C. and must therefore be dried over sulphuric acid at ordinary temperatures; even then it sometimes decomposes. Over sulphuric acid in vacuo, it gives off all its ammonia and leaves hæmatein (Erdmann). According to Hesse, it gives off all its water and ammonia at 130° C., leaving hæmatein as a very hygroscopic powder, having a blackish violet colour with green iridescence.

Hæmatein thus obtained contains, according to Hesse's analysis, 67·66 per cent. carbon, and 3·50 hydrogen, agreeing nearly with the formula $C^{16}H^{10}O^5$, which requires 68·08 C and 3·54 H. Erdmann found in his hæmatein 62·66 per cent. C and 4·16 H (mean), whence he deduced the formula $C^{16}H^{20}O^{14}$. Gerhardt (*Traité*, iv. 302) proposed the formula $C^{16}H^{12}O^6$, which, however, does not agree very well with Erdmann's analyses, requiring 64·0 per cent. C and 4·0 H. Hesse suggests that Erdmann's hæmatein may be a dibasic acid, $\left.\begin{matrix}C^{16}H^{10}O^4\\H^2\end{matrix}\right\}O^2$, and the product, $C^{16}H^{10}O^5$, obtained by himself, the corresponding anhydride; on this supposition, the two ammonium-salts above mentioned are, perhaps, $\left.\begin{matrix}C^{16}H^{10}O^4\\(NH^4)^2\end{matrix}\right\}O^2$ and $\left.\begin{matrix}C^{16}H^{10}O^4\\H.NH^4\end{matrix}\right\}O^2.3H^2O$.

The solution of hæmateate of ammonium forms coloured precipitates with many metallic salts: with acetate of *lead* it produces a deep blue precipitate; with sulphate of *copper*, violet-blue; with *protochloride of tin*, violet; with *iron-alum*, black. With chloride of *barium* it forms a dark purple liquid, which becomes brown on exposure to the air. It reduces nitrate of *silver*, but has no action on mercuric chloride. According to Hesse, it forms with *chloride of barium*, *chloride of calcium*, and especially with *chloride of sodium*, precipitates of various colours; no precipitate with hyposulphite of sodium; with *acid sulphite of ammonium*, a gelatinous precipitate, which disappears on boiling.

HÆMATIN or **HÆMATOSIN.** The red colouring matter of the blood-corpuscles. (See Blood, i. 607.) Lehmann (Compt. rend. xl. 385) first showed that it may be obtained in the crystalline state. R. Schwarz (Zeitschr. f. die ges. Naturwissench. xi. 225) prepares it in this state by submitting the comminuted clot of ox-blood, freed as much as possible from serum, to pressure, and agitating the expressed liquid by small portions with a saturated solution of oxalic acid, with addition of alcohol and a large quantity of ether. The clear dark brown solution, decanted after a few minutes and left to stand for some weeks over chloride of calcium, deposits the hæmatin in small black nodules made up of cubes, which may be freed from admixed oxalate of calcium by means of dilute hydrochloric acid. Less distinct crystals may be obtained by leaving the ethereal solution to evaporate freely; but the quantity is always small. A solution of hæmatin obtained as above from horse-blood, yielded, on standing, small rush-shaped or spindle-shaped crystals, red-brown by transmitted light. Hæmatin may be obtained in the amorphous state by distilling off about a third of the ether from the solution, and mixing the residue with a large quantity of water. The black flocks thus precipitated are washed with water by decantation; then boiled with strong acetic acid, to free them from albuminous compounds, as long as the liquid is rendered turbid by ferrocyanide of potassium; and, lastly, the precipitate is boiled with water, alcohol, and ether in succession, and then again treated with water. The crystallised compound may be subjected to the same treatment without undergoing any alteration. Hæmatin thus prepared is tasteless and inodorous, insoluble in water, cold alcohol, and ether; partially (?) soluble in hot alcohol, easily in acidulated alcohol, whence it is precipitated by water. The solution in acidulated alcohol is decolorised by peroxide of lead. Hæmatin likewise dissolves easily in slightly alkaline liquids, but not in strong sulphuric or hydrochloric acid. Silver, lead, and copper-salts form precipitates in the ammoniacal solution. Hæmatin, when burnt, leaves a residue of ferric oxide mixed with small quantities of calcic phosphate.

The following analyses of hæmatin by Schwarz, give results not differing greatly from those formerly obtained by Mulder (whence the latter deduced the formula $C^{32}H^{32}FeN^4O^8$), but agreeing better with the formula $C^{68}H^{32}FeN^4O^8$.

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	Calculation.	Schwarz. Amorphous.	Schwarz. Amorphous.	Schwarz. Crystallised from horse-blood.	Mulder.
C^{36}	66·35	64·12	63·89	64·03	65·58
H^{22}	5·28	5·31	5·28	5·60	5·30
Fe	6·73	6·36	. .	. .	6·73
N^3	10·10	10·19	. .	10·17	10·54
O^8	11·54	11·00	. .	. .	11·85
Phosphate of calcium	. .	3·02			
	100·00	100·00			100·00

When an alcoholic solution of crystallised hæmatin is boiled with nitric acid, the whole of the nitrogen of the hæmatin is removed, and a non-azotised acid is formed, together with a substance which reduces cupric oxide in alkaline solution, and ferments with yeast, yielding alcohol and carbonic acid.

The name *hæmatin* is sometimes also used as a synonyme of HÆMATOXYLIN.

HÆMATINONE. A red glass known to the ancients, and used for mosaics, ornamental vases, &c.; it is mentioned by Pliny, and occurs pretty frequently among the ruins of Pompeii. Its colour is a fine red, intermediate between red lead and vermilion. It is opaque, harder than common glass, takes a fine polish, has a conchoïdal fracture, and a specific gravity of 3·5. The red colour, which is due to red oxide of copper, is completely destroyed by fusion, and cannot be restored by any addition whatever. The fused mass has a greenish black colour, which reducing agents merely convert into a muddy brown-red. Hæmatinone contains no tin, and no colouring substance except cuprous oxide.

This antique glass may be exactly imitated by the following process, discovered by Pettenkofer (Dingl. pol. J. cxlv. 122):—100 pts. of silica, 11 lime, 1 magnesia, 33 litharge, and 50 carbonate of soda, are fused together, and to the clear white glass thus produced are added 25 pts. of scale oxide of copper, somewhat later 2 pts. of scale oxide of iron, and, lastly, a small quantity of charcoal. On leaving the fused mass to cool slowly, a liver-coloured glass is obtained, which, when further heated (for 6 to 12 hours) till it softens, is converted into hæmatinone of a splendid red colour, in consequence of the separation of a red cuprous compound within its mass.

A more fusible glass, made by melting together 100 pts. silica, 10 lime, 0·5 magnesia, 40 litharge, 60 carbonate of soda, 30 scale oxide of copper, 2 alumina, and 3 scale oxide of iron, exhibits, after once slow cooling in the air-furnace, a great number of red points, diffused through a yellowish vitreous mass; on cutting and polishing this glass, the red points appear as beautiful tufts of needle-shaped crystals.

When part of the silica in hæmatinone is replaced by boric anhydride (by adding borax to the melted mass), a dark-coloured, dichroïtic, crystalline compound is obtained, called astralite (i. 429).

Pettenkofer is of opinion that the same crystalline cuprous compound (whether pure cuprous oxide, or more probably cuprous silicate) which imparts the red colour to hæmatinone, constitutes likewise the crystalline spangles contained in aventurin glass (i. 477), which in fact he has produced by fusing hæmatinone with a quantity of iron filings, sufficient to reduce about half the copper contained in it to the metallic state (the metal then settling down in the form of a regulus, and leaving a deep greenish black, scarcely transparent glass above), heating this glass for some time to the temperature at which it softens, and then leaving it to cool very slowly. (Jahresb. d. Chem. i. 1061; ix. 798.)

HÆMATITE. Native sesquioxide of iron. (See IRON, OXIDES OF.)

HÆMATO-CRYSTALLIN. A crystalline substance obtained from blood (i. 606). It has the composition of the albuminoïds, and if quite pure would probably be colourless, but it has never yet been obtained perfectly free from hæmatin.

HÆMATO-GLOBULIN. Syn. with HÆMATO-CRYSTALLIN.

HÆMATOÏDIN. A crystalline substance often found in extravasated blood (i. 607). It appears to be produced by the decomposition of hæmatin; but the nature of the transformation has not been exactly made out. According to Verdeil and Dollfus (Compt. rend. xxx. 306), crystals resembling hæmatoïdin may be obtained from ox-blood by filtering it after coagulation by heat; evaporating the solution to a syrup, and mixing it with alcohol; strongly concentrating the liquid filtered from the resulting precipitate; and mixing it, when cold, with dilute sulphuric acid. Fat globules then separate on the surface of the liquid, and sometimes red crystals resembling hæmatoïdin.

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Robin (Compt. rend. xli. 506) found a considerable quantity of hæmatoïdin in an hepatic cyst, forming hard, brittle prisms of 118° and 62°, and of a bright, orange-red colour. According to Valentiner (Jahresb. f. Chem. 1859, p. 656), gall-stones, bile, and the livers of persons affected with jaundice, yield, when treated with chloroform, a crystalline substance differing from all previously known ingredients of bile, and agreeing in all respects with hæmatoïdin.

HÆMATOSIN. See HÆMATIN.

HÆMATOXYLIN, also called *Hematin.* $C^{16}H^{14}O^6$. (Chevreul, Ann. Chim. lxxx. 128.—Golfier-Besseyre, Ann. Ch. Phys. [2] lxx. 272.—Erdmann, Ann. Ch. Pharm. xliv. 292.—Leblanc, *Traité de Chimie* de Dumas, viii. 102.—O. Hesse, J. pr. Chem. lxxv. 218; Ann. Ch. Pharm. cix. 332.)—A crystalline substance contained in logwood (*Hæmatoxylon Campechianum*), and the source of the colouring properties of that well-known dye. In the pure state, however, it has little or no colour, but is converted into a colouring matter under the influence of alkalis and oxygen.

It is prepared by leaving the commercial extract of logwood—previously mixed with quartz-sand to prevent agglomeration—in contact with 5 or 6 times its volume of ether (not anhydrous) for several days, agitating from time to time; then decanting the brownish-yellow solution; distilling off the ether; mixing the syrupy residue with water; and leaving it to itself in a loosely covered vessel. If no water were added, the liquid would simply dry up to a gummy mass; but, if a sufficient quantity of water is present, the hæmatoxylin crystallises in the course of a few days. The crystals are washed with water and freed from adhering mother-liquor by pressure between filtering paper. The mother-liquor mixed with the wash-water yields another crop of crystals by spontaneous evaporation. A kilogramme of logwood treated several times with ether yields from 100 to 120 grms. of hæmatoxylin. (Erdmann.)

Hæmatoxylin thus prepared has more or less of a yellow colour, but by recrystallisation from water containing a little sulphite of ammonium, it may be obtained in colourless crystals. (Hesse.)

Hæmatoxylin forms two kinds of crystals containing respectively 3 and 1 at. water. The trihydrated crystals, $C^{16}H^{14}O^6.3H^2O$, obtained as above, belong to the dimetric system. Ordinary combination $\infty P\infty$. P, with $P\infty$ subordinate. Length of principal axis = 0·63 (nearly). Angle of the terminal edges of the primitive octohedron, P = 124°. The crystals are transparent, generally very brilliant, and sometimes of considerable length. They give off their water (15·1 per cent.) in vacuo at ordinary temperatures.

The *monohydrate*, $C^{16}H^{14}O^6.H^2O$ (containing 5·6 water), is obtained by leaving a solution supersaturated at mean temperature to stand for some time, in crystals of considerable size, with smooth and sometimes curved faces, and consisting, according to a preliminary determination by Naumann, of hemihedral trimetric combinations, $oP . \frac{P}{2} . m\breve{P}\infty$. The same hydrate is obtained in granular crystals, by pouring a solution of hæmatoxylin, supersaturated at the boiling heat, into a cold vessel containing a small quantity of solution of acid sulphite of ammonium. (Hesse.)

Dehydrated hæmatoxylin contains, according to Erdmann's analyses, 63·17—63·66 per cent. carbon, and 4·65—4·70 hydrogen, whence Erdmann deduced the formula $C^{16}H^{12}O^{5}$. Gerhardt, however (*Traité*, iv. 299), suggested the more probable formula, $C^{16}H^{14}O^6$, which requires 63·5 per cent. C, 4·5 H, and 31·9 O.

Hæmatoxylin dissolves slowly and sparingly in cold *water*, easily in *alcohol* and *ether* (Erdmann). It dissolves in a saturated solution of *borax* more easily than in pure water, forming a neutral or slightly acid liquid, which exhibits a bluish fluorescence, and from which the borax is not precipitated by alcohol. This solution, mixed with hydrochloric, acetic, or sulphuric acid, solidifies to a dense mass, in which granular crystals of monohydrated hæmatoxylin quickly form; but on addition of solution of chloride of sodium, potassium, or ammonium, ferrocyanide of potassium, or acid sulphite of ammonium, it deposits hæmatoxylin as a white amorpheus mass. When acid sulphite of ammonium is added by drops to the same solution, hæmatoxylin is at first deposited in the form of an amorphous gummy precipitate, which re-dissolves on boiling the liquid, and reappears on cooling; but on continuing the addition of the acid sulphite to the syrupy liquid, a point is at length attained at which the amorphous hæmatoxylin disappears, and crystals of hæmatoxylin are soon afterwards obtained. When amorphous hæmatoxylin is dissolved in boiling water, and a drop of hydrochloric acid added to the solution, crystals of hæmatoxylin, generally the monohydrate, are soon deposited. Hesse.)

Hæmatoxylin dissolves abundantly in a warm solution of *hyposulphite of sodium*, forming a purple liquid, which deposits amorphous hæmatoxylin on cooling. It dis-

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solves with some difficulty in solution of *chloride of sodium*, more easily in a saturated solution of *chloride of barium* (this solution at first depositing crystals of the trihydrate, which gradually give place to those of the monohydrate), very abundantly in solution of *ordinary phosphate of sodium*, forming a liquid which behaves like the solution of hæmatoxylin in borax above mentioned, excepting that it exhibits a basic reaction. (Hesse.)

Hæmatoxylin has a strongly saccharine taste, like that of liquorice, very persistent, and without astringence or bitterness. Its solutions turn the plane of polarisation to the right. It reduces cupric oxide in an alcoholic solution containing alkali.

An aqueous solution of hæmatoxylin is not altered by contact with pure air or oxygen gas; but if the slightest trace of *ammonia* is present in the air, the liquid acquires a yellowish red colour, arising from the formation of hæmateate of ammonium; probably thus:

$$C^{16}H^{14}O^6 + O + NH^3 = C^{16}H^9(NH^4)O^5 + 2H^2O.$$

Hæmatoxylin melts in its water of crystallisation when moderately *heated*, and is completely carbonised at higher temperatures. *Chlorine* converts it into an uncrystallisable mass. With *nitric acid* it forms oxalic acid. *Sulphuric* and *hydrochloric acids* have but little action upon it.

With *bases*, hæmatoxylin forms compounds which, on exposure to the air, are converted into hæmateates. *Baryta-water*, added to a solution of hæmatoxylin freed from air by boiling, forms a white precipitate which soon turns blue if the air has access to it. *Potash* imparts to the solution a violet colour, quickly changing to purple and brown. With acetate of *lead*, neutral or basic, the solution yields a white precipitate, which quickly turns blue; with *cupric* acetate or sulphate, a greenish grey precipitate, which soon becomes dark blue with a coppery lustre. *Dichloride of tin* forms a rose-coloured precipitate, which does not change colour. *Iron alum* forms, after a while, a slight blackish violet precipitate. *Common alum* colours the solution light red, but does not produce a precipitate. *Chloride of barium* first colours the liquid red, and then forms a red precipitate. The solution of hæmatoxylin quickly reduces nitrate of *silver* and chloride of *gold*.

HÆMIN. A crystallised, intensely red substance, which may be prepared from blood in various ways, but is difficult to obtain in the pure state, and has therefore not been analysed. The crystals are obtained immediately on mixing blood, either fresh or boiled, with strong acetic acid. No crystals are formed, however, when blood coagulated by boiling is first washed with water and then treated with acetic acid (Teichmann, Pfeufer and Henle's Zeitschr. f. rat. Medicin, iii. 357; viii. 141). According to Krauss (Jahresb. f. Chem. 1861, p. 792), human blood may be distinguished with certainty from that of the ox, sheep, pig, mouse, or poultry, by the characters of the hæmin-crystals obtained from it.

HAFREFJORDITE. Oligoclase from Hafrefjord, in Iceland.

HAIDINGERITE. A hydrated arsenate of calcium, $2Ca''HAsO^4.3H^2O$, supposed to be from Baden or Joachimsthal, associated with pharmacolite. Occurs in minute crystals belonging to the trimetric system, mostly congregated in botryoïdal forms and drusy crusts. Specific gravity 2·848. Hardness 1·5 to 2·5. Lustre vitreous. Colour white. Streak white. Transparent or translucent. Sectile; their laminæ slightly flexible. (Dana, ii. 413.)

Crystals having the form and composition of haidingerite may be produced artificially by digesting carbonate of calcium at ordinary temperatures with excess of aqueous arsenic acid. (Debray, Ann. Ch. Phys. [3] lxi. 419.)

HAIR. Hair consists of a cylindrical tube clothed with minute scales, having their points directed towards the free extremity. The tube is filled with an oil, which gives the colour to the hair; in white hair this oil is colourless.

In the normal state hair is insensible, strongly electric, and a bad conductor of heat. In contact with the air, it swells and absorbs moisture, but does not putrefy. Chlorine first bleaches and then converts it into a resinous matter resembling turpentine.

Hair is insoluble in water. Heated with water in a sealed tube, it is decomposed, with liberation of sulphydric acid. A similar decomposition takes place with aqueous potash. Nitric acid turns it yellow, forming oxalic acid, sulphuric acid, and a peculiar bitter substance. Hydrochloric and sulphuric acids dissolve it, forming rose-coloured solutions. Alkalis dissolve it. Many salts and metallic oxides, and likewise certain organic substances, change the colour of red or white hair to black. A solution of nitrate of silver in ether, or the same salt mixed with lard, oil, slaked lime, or pyrogallic acid is commonly used for blackening hair.

Hair, when heated, becomes hard, swells and emits an odour of burnt horn, and in the open air, takes fire, burns with a bright flame, and leaves a residue of charcoal. By dry distillation it yields oily and ammoniacal products.

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According to Von Laer, human hair contains 49·8 per cent. carbon, 6·4 hydroge 17·1 nitrogen, 5·0 sulphur, and 26·7 oxygen. It leaves by calcination from 0·32 1·85 per cent. of ash, consisting of 0·17 to 0·93 soluble matter, 0·658 to 0·390 oxi of iron, and 0·000 to 0·528 earthy salts. (Pelouze et Frémy, *Traité*, vi. 244.)

HAIR-SALT. A term applied to native *sulphate of aluminium*, $Al^2(SO^4)^3.9H^2$ and to *iron-alum*, $Al'''Fe(SO^4)^2.12H^2O$, these salts sometimes occurring in delica fibrous masses. (See ALUM and SULPHATES.)

HALLITE. Basic sulphate of aluminium, $2(Al^2O^3.SO^3).3H^2O$. (Syn. wi WEBSTERITE.)

HALLOYSITE or **HALLOYTE.** A hydrated silicate of aluminium contai ing a larger proportion of water than ordinary clay, which it otherwise resembl After drying in the air at ordinary temperatures, it retains nearly $2H^2O$, but drying in the kiln, the proportion of water is reduced to nearly that of common clay, v $Al^2O^3.SiO^2 + H^2O$. It occurs in white, soft, smooth masses, with conchoïdal wa fracture, adhering to the tongue, opaque or translucent at the edges only. Wh immersed in water, it does not fall to pieces but becomes more translucent. It readily decomposed by sulphuric acid. The following are analyses:—

	Berthier.				Boussingault.	
	a 1.	*a* 2.	*b* 1.	*b* 2.	*c* 1.	*c* 2.
Alumina . .	35·49	32·4	39·06	34·0	39·4	35
Silica . . .	47·75	43·6	44·94	39·5	44·9	40
Water . . .	16·76	23·0	16·00	26·5	15·7	25
	100·00	99·0	100·00	100·0	100·0	100

	Oswald.	Dufrénoy.	
	d.	*e.*	*f.*
Alumina	35·00	33·66	32·45
Silica	40·25	40·66	43·10
Water	24·25	24·83	22·30
Magnesia	0·25		1·70
	99·75	99·15	99·55

a, from Houscha, near Bayonne; (1) kiln-dried; (2) air-dried;—*b*, from Anglen near Liége; (1) kiln-dried; (2) air-dried;—*c*, from Guateque, in New Granad (1) dried at 100° C.; (2) air-dried; this specimen contained a trace of sal-ammonia —*d*, from Upper Silesia, containing a trace of manganese;—*e*, from La Vouth;—*f*, fro Thiviers. (Gm. iii. 417.)

HALOGEN. The electro-negative radicle of a haloïd-salt.

HALOÏD SALTS. Berzelius applied this term to salts consisting of a met united with an electro-negative radicle, viz. *chlorides*, *bromides*, *iodides*, *cyanides*, & designating by the term, AMPHID-SALTS, those which were supposed to result fro the union of two binary compounds containing a common element, viz. the oxyge salts, sulphur-salts, selenium-salts, and tellurium-salts. The distinction between the two classes of salts is no longer retained, but the term *haloïd* is still occasional applied to the chlorides, bromides, iodides, fluorides, and cyanides.

HALOTRICHINE. A silky iron-alum, from the Solfatara, near Naples. (S SULPHATES).

HALOTRICHITE. A name applied sometimes to native iron-alum, sometim to native hydrated sulphate of aluminium. (See SULPHATES.)

HAMATHIONIC ACID. An acid produced by the action of sulphuric ac on euxanthic acid. Its composition has not been exactly determined. The bariu salt contains 31·4 per cent. baryta; the lead-salt, 61·6 to 62·4 oxide of lead. (S EUXANTHIC ACID, ii. 610.)

HAMPSHIRITE. (See STRATITE.)

HARDNESS OF MINERALS. A harder body is distinguished from a soft either by attempting to scratch one with the other, or by trying each with a file. give a definite character to the results thus obtained, Mohs introduced a scale hardness, consisting of ten minerals, gradually increasing in hardness from 1 to 10, vi

1. *Talc:* common laminated, light-green variety.
2. *Gypsum:* a crystallised variety.
3. *Calc-spar;* transparent variety.
4. *Fluor-spar:* crystalline variety.
5. *Apatite:* transparent variety.

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5·5 *Scapolite:* crystalline variety.
6. *Felspar:* (orthoclase); white cleavable variety.
7. *Quartz:* transparent.
8. *Topaz:* transparent.
9. *Sapphire:* cleavable varieties.
10. *Diamond.*

The hardness of any given mineral may be determined by attempting to scratch it with some of the above minerals, or by trying to scratch a smooth surface of the successive members of the scale with a sharp corner of the substance to be examined; thus, if it scratches fluor-spar and is scratched by apatite, the hardness is between 4 and 5.

Or again, the relative hardness of a mineral may be determined by abrading one of its edges with a file. If the file abrades the mineral under trial with the same ease as fluor-spar, and produces an equal depth of abrasion with the same force, the hardness is said to be 4. If the mineral is abraded more easily than fluor-spar, but less easily than apatite, the hardness may be 4·25 or 4·5. In making these comparative trials, care must be taken to apply the file to edges of equal obtuseness. That part also of the specimen should be selected which has not been altered by exposure, and has the highest degree of transparency and compactness of structure. The pressure for determination should be rather heavy, and the file should be passed three or four times over the specimen.

Certain varieties of some minerals give a low degree of hardness under the file, owing either to impurities or imperfect aggregations of particles, whilst they scratch a harder species, showing that the particles are hard, but loosely aggregated; this peculiarity is exhibited by certain varieties of chiastolite, spinel, and sapphire.

Many minerals—kyanite and mica, for example—present different degrees of hardness on dissimilar faces. This inequality, like difference of colour, lustre, &c., in the faces, is confined to those primary forms which are developed upon unlike axes. (Dana, i. 180.)

HARMALA, ALKALOÏDS OF. (Gerh. iv. 9.—Handw. d. Chem. iii. 769.)—The seeds of the *Peganum Harmala*, a plant growing abundantly on the steppes of Southern Russia, especially in the Crimea, contain two organic bases called harmaline and harmine, probably in the form of phosphates; they are found in the seed-coating, not in the kernel. To obtain these alkaloïds, the pulverised seeds are exhausted in a percolating apparatus with water acidulated with acetic or sulphuric acid; and the brownish yellow extract, which contains the bases in the form of acetates, together with earthy phosphates, colouring matter, &c., is mixed with a solution of common salt, whereupon the hydrochlorates of the alkaloïds, which are insoluble in that liquid, are precipitated together with colouring matter. Nitrate of sodium may also be used instead of the chloride, provided care be taken that the extract of the seeds does not contain free sulphuric acid, as the nitric acid which would then be liberated might decompose the alkaloïds. The precipitate is collected on a filter, and washed with brine until the whole of the mother-liquor is removed; then dissolved on the filter with cold water, which leaves part of the colouring matter undissolved. The solution, treated with animal charcoal, and then at a temperature of 50° to 60° C. with ammonia added by small portions, yields the alkaloïds in the pure state, nearly the whole of the harmine being thrown down before the harmaline begins to separate. As soon as the latter body makes its appearance,—which may be known by examining the precipitate from time to time with the microscope, harmine crystallising in needles, while harmaline forms leafy scales,—the solution must be filtered hot, and the harmaline precipitated from it by ammonia.

The seeds contain about 4 per cent. of alkaloïds, of which one-third consists of harmine, and two-thirds of harmaline.

HARMALA RED. The seeds of harmala contain also a red colouring matter, which may be extracted by digesting them with alcohol for 8—14 days. It is insoluble in water, easily soluble in ether, and dissolves in all proportions in absolute alcohol. It unites with acids, forming red salts, and dyes wool or silk mordanted with acetate or sulphate of alumina, from the lightest rose-colour to the deepest scarlet. The colours do not, however, appear to be very fast. (Gm. xvi. 119.)

HARMALINE. $C^{13}H^{14}N^2O$.—Discovered by Göbel in 1837 (Ann. Ch. Pharm. xxxviii. 363); afterwards more minutely examined by Fritzsche (*ibid.* lxiv. 360; lxviii. 351, 355; lxxii. 306; lxxxviii. 327). It is colourless when pure; if it has a yellowish or brownish tint, it may be purified by suspending it in water, adding acetic acid in sufficient quantity to dissolve it, filtering to separate colouring matter, then precipitating with chloride or nitrate of sodium, or hydrochloric acid, washing the precipitate on a filter with a dilute solution of the reagent employed, dissolving it in tepid

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water, treating the solution with animal charcoal till it exhibits a light yellow c and precipitating by caustic potash.

Harmaline crystallised from alcohol forms octahedrons belonging to the trin system, modified by the faces $\infty\breve{P}\infty$, $\infty\dot{P}\infty$, and $\dot{P}\infty$. Ratio of the vertical t horizontal axes, 1 : 1·804 : 1·415. Angles of the terminal edges in P = 116° 34 131° 18′; of the lateral edges in the same = 83° 54′. It is sparingly soluble in and ether, moderately soluble in cold alcohol, and very freely in boiling alcoho has a faint bitter taste; and colours the saliva yellow.

Harmaline, when heated, melts, gives off white vapours and becomes carbo Heated in a tube, it yields a white mealy sublimate. Oxidising agents, under c circumstances, convert it into a red colouring matter, insoluble in water, solu alcohol. By some oxidising agents, however, harmaline is converted into harmi loss of 2 at. of hydrogen; this change takes place when the acid chromate of harm is heated to 120° C., or when harmaline is heated with hydrochloric acid and al to which a little nitric acid is added. When nitrate of harmaline is heated with holic hydrochloric acid, the harmaline is converted into harmine. Harmaline, with excess of *nitric acid*, yields, first, nitroharmaline, then, by longer boiling, n harmine: with boiling *nitromuriatic acid*, it forms chloronitroharmine.

The salts of harmaline are yellow, have a bitter taste, and are for the mos easily soluble and crystallisable.

The *acetate* is obtained by spontaneous evaporation of a solution of harmali acetic acid, in the form of a syrup which becomes crystalline after a while. A sol of the acetate, mixed with acid carbonate of potassium, yields *acid carbonate of h line*, in the form of a precipitate composed of fine needles. The neutral alkaline c nates either form no precipitate with the salts of harmaline, or merely throw dow base.

The *neutral chromate* is a sparingly soluble, yellow, crystalline salt, which m obtained by adding acetate of harmaline drop by drop to a solution of neutral chr of potassium, saturated in the cold, filtering from the precipitate of harmaline produced, and adding more acetate of harmaline to the filtrate. The *acid chro* $2C^{13}H^{14}N^2O.H^2O.2CrO^3$, is produced by adding acid chromate of potassium to a c solution of harmaline, and separates immediately in oily drops, which, after a w become crystalline. When heated to 120° C., it is rapidly decomposed, yielding a limate of *harmine* and leaving a dark-coloured residue containing chromium.

The *hydrochlorate*, $C^{13}H^{14}N^2O.HCl.2H^2O$, forms long prismatic needles conta 12·3 per cent. water of crystallisation. It is moderately soluble in water and in alc The *chloroplatinate*, $2(C^{13}H^{14}N^2O.HCl).PtCl^4$, is a yellow precipitate.

The *hydrocyanate* forms a peculiar alkali. The *hydroferrocyanate* is a bric crystalline powder; the *hydroferricyanate* forms long dark green prisms. The *su cyanate* forms silky needles, sparingly soluble in cold, more soluble in boiling wa

Nitrate of harmaline, obtained by precipitating the acetate with dilute nitric a nitrate of ammonium, forms needles sparingly soluble in pure water, and almost luble in water containing nitric acid.

Oxalates.—When aqueous oxalic acid is boiled with excess of harmaline, cryst the neutral salt separate on cooling; and oxalic acid, added to the solution of crystals, precipitates the acid oxalate of harmaline.

Sulphates.—By digesting dilute sulphuric acid with excess of harmaline, and e rating the filtrate, the neutral sulphate is obtained as a yellow resin, which, whe over oil of vitriol, changes to a radio-crystalline mass.

Sulphite.—The solution of harmaline in aqueous sulphuric acid dries up to a y resin, exhibiting no traces of crystallisation.

Sulphydrate.—By mixing concentrated solutions of sulphydrate of ammoniu acetate of harmaline, slender prisms are obtained which quickly decompose on exp to the air, after separation of the mother-liquor.

Hydrocyan-harmaline, $C^{14}H^{15}N^3O = C^{13}H^{14}N^2O.HCy$, is a base containin elements of harmaline and hydrocyanic acid. It is obtained by dissolving harm in dilute boiling hydrocyanic acid and filtering hot, being then deposited in cr on cooling; or by pouring a solution of cyanide of potassium into a solution of of harmaline, or caustic potash into a solution of a salt of harmaline previ mixed with hydrocyanic acid. From aqueous solutions it is deposited in amor flocks, which give off hydrocyanic acid when dried in the air; the decomposition however, be prevented by dissolving the powder, while yet moist, in hot alcohol. still contains harmaline, it may be purified by suspending it in water and a acetic acid, which readily dissolves the harmaline, but exerts little or no action o hydrocyan-harmaline.

This base, when pure, forms thin rhomboïdal tables, which, when dry, under alteration by exposure to the air, or in vacuo, or even at 100° C. At a higher

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perature, or when boiled with water or alcohol, it is resolved into harmaline and hydrocyanic acid. Suspended in water and boiled with a large excess of nitric acid, it is decomposed, giving off red vapours, and yielding a purple solution which deposits non-crystalline grains of a fine red colour, changed to green by ammonia. Hydrocyan-harmaline, heated with hydrochloric acid and chloride of potassium, yields a resinous product.

The salts of hydrocyan-harmaline are even less stable than those of harmaline. The base does not appear to combine with all acids. The hydrochlorate, $C^{13}H^{11}N^3O.CyH.HCl$, is a crystalline powder composed of small octahedrons with a rhombic base and secondary faces, whereas hydrochlorate of harmaline, when examined by the microscope, appears like an aggregation of long yellow prisms. The *nitrate* and *sulphate* are also crystalline.

Nitroharmaline. $C^{13}H^{12}N^2O^2 = C^{13}H^{12}(NO^2)N^2O$. *Chrysoharmine.*—This body, which is derived from harmaline by the substitution of 1 at. nitryl, NO^2, for 1 at. hydrogen, may be prepared:—1. By suspending 1 pt. of harmaline in 6 or 8 pts. of alcohol of 80 per cent., adding 2 pts. of strong sulphuric acid, and, when the solution is complete, 2 pts. of moderately concentrated nitric acid; heating the mixture on the water-bath; and as soon as the reaction, which is very brisk, is over, cooling it quickly to prevent secondary decompositions. The liquid then deposits sulphate of nitroharmaline, which is to be washed with alcohol containing sulphuric acid, thon dissolved in warm water, and precipitated by dilute potash or ammonia. If the nitroharmaline thus precipitated contains harmine or undecomposed harmaline, it may be freed therefrom by means of sulphurous acid, which forms a sparingly soluble salt with nitroharmaline, but very soluble salts with the other two bases.—2. By a process exactly similar to that which will be hereafter described for the preparation of nitroharmine, excepting that the nitric acid used must be weaker, viz. of specific gravity 1·12 instead of 1·40.

Nitroharmaline, precipitated from its salts by an alkali, is an orange-coloured powder composed of microscopic prisms; larger crystals are deposited from the alcoholic solution. It is but sparingly soluble in cold water, to which, however, it imparts a yellow colour; boiling water dissolves it much more freely. It is more soluble in alcohol than harmine or harmaline; sparingly soluble in cold ether, more soluble in hot ether. It dissolves in oils, both fixed and volatile; also in hot rock-oil. It melts at 120° C.

Heated with ammoniacal salts it decomposes them, expelling the ammonia. Nitric acid converts it into nitroharmine.

The salts of nitroharmaline are yellow. The *hydrochlorate*, $C^{13}H^{12}(NO^2)N^2O.HCl$, crystallises in small prisms; its solution, mixed with tetrachloride of platinum, yields the *chloroplatinate*, $2(C^{13}H^{12}(NO^2)N^2O.HCl).PtCl^4$, as a yellow precipitate, which ultimately assumes the form of minute prisms.

The *nitrate* crystallises in yellow needles, rather sparingly soluble in water, especially if it contains a little nitric acid. A perfectly neutral solution of this salt, mixed with ammoniacal nitrate of silver, yields a yellowish red flocculent precipitate, consisting of *argento-nitroharmaline*, $C^{13}H^{12}Ag(NO^2)N^2O.H^2O$.

A compound of *nitroharmaline with nitrate of silver* is obtained in light yellow crystalline flakes on mixing an alcoholic solution of nitroharmaline with nitrate of silver.

The *neutral sulphate* is obtained as a crystalline precipitate on saturating a solution of the acetate with sulphate of ammonium. The *acid sulphate*, $C^{13}H^{12}(NO^2)N^2O.H^2SO^4$, is produced by dissolving the base in excess of sulphuric acid, mixed with alcohol, or by dissolving it in strong sulphuric acid, and pouring the solution, drop by drop, into cold water. It is a pale yellow crystalline powder, nearly insoluble in cold water.

The *sulphite* is very little soluble in cold water, especially if acidulated with sulphurous acid.

The *acetate* is soluble; the *oxalate* crystallisable. The *hydroferrocyanate* is a yellow crystalline precipitate. The *hydroferricyanate* separates in oily drops, which solidify, after a while, to a crystalline powder. The *sulphocyanate* forms sparingly soluble microscopic needles.

Hydrocyano-nitroharmaline, $C^{13}H^{12}(NO^2)N^2O.CyH$, is obtained by dissolving nitroharmaline in a hot alcoholic solution of hydrocyanic acid; also, by leaving a concentrated solution of acetate of nitroharmaline, mixed with hydrocyanic acid, to evaporate; or by adding ammonia to a salt of nitroharmaline containing hydrocyanic acid. It forms slender yellow needles, which give off the odour of ammonia when moist, but are permanent when dry. By boiling with water, it is resolved into nitroharmaline and hydrocyanic acid. Decomposed also by strong ammonia or potash. It dissolves in strong sulphuric acid, and the solution, poured into a small quantity of water, yields needles, apparently consisting of an insoluble sulphate.

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HARMINE. $C^{13}H^{12}N^2O$. (Fritzsche, *loc. cit.*, p. 7.)—This alkali, which contains 2 at. H less than harmaline, may be obtained either directly from the seeds of *Peganum harmala*, in the manner already described, or as a product of the oxidation of harmaline. Acid chromate of harmaline, heated to 120° C., decomposes suddenly with evolution of heat, and produces harmine, part of which volatilises and condenses on the sides of the vessel. A better process is to heat harmaline with a mixture of equal parts of hydrochloric acid and alcohol, to which a little nitric acid is added. The conversion of the harmaline is complete soon after the liquid begins to boil, and on cooling, hydrochlorate of harmaline is abundantly deposited in slender needles. The solution of this salt, decomposed by ammonia, yields the base.

Harmine forms rhomboïdal prisms of 124° 18′, and 55° 42′, nearly insoluble in *water*, very sparingly soluble, at ordinary temperatures, in *alcohol* and in *ether*. It is a weaker base than harmaline; nevertheless it expels ammonia from its salts at the boiling heat.

The salts of harmine are colourless, and mostly crystalline; their solutions have a yellow tint when concentrated, bluish when dilute. Alkalis and alkaline carbonates decompose them, precipitating the base.

The *acid chromate*, $2C^{13}H^{12}N^2O.H^2O.2Cr^2O^6$, is always formed on mixing an acid solution of harmaline with a soluble chromate. It is decomposed by heat, yielding a peculiar base.

The *hydrochlorate*, $C^{13}H^{12}N^2O.HCl$, forms needles containing 12·38 per cent. water, which they give off at 100° C. From alcohol, the salt is deposited in the anhydrous state. The *chloroplatinate*, $2(C^{13}H^{12}N^2O.HCl).PtCl^4$, is a flocculent precipitate, becoming crystalline when heated. The *chloromercurate* is deposited as a curdy precipitate from cold solutions, and crystalline from hot solutions. The *hydrobromate* and *hydriodate* resemble the hydrochlorate.

The *hydroferrocyanate* and *hydroferricyanate* are obtained as yellow precipitates.

The *nitrate* forms yellow needles, sparingly soluble in cold water, still less in water acidulated with nitric acid.

The *neutral oxalate* is a crystalline precipitate. The *acid oxalate*, $C^{13}H^{12}N^2O.C^2H^2O^4.H^2O$ forms radiating needles, containing 5·67 per cent. water, which they give off at 100° C.

The *neutral sulphate*, $2C^{13}H^{12}N^2O.H^2SO^4.2H^2O$, obtained by dissolving an excess of harmine in dilute sulphuric acid and evaporating, forms concentrically grouped needles containing 6·57 per cent. of water. The *acid sulphate*, $C^{13}H^{12}N^2O.H^2SO^4$, obtained by adding excess of sulphuric acid to a solution of harmaline in boiling alcohol, forms crystals similar in form, but anhydrous.

The *sulphocyanate* is obtained by precipitation in yellow needles.

Substitution-derivatives of Harmine.

Dichlorharmine. $C^{13}H^{10}Cl^2N^2O$. (Fritzsche, Petersb. Acad. Bull. v. 12.)—Produced by the action of hypochlorous acid on harmine. To prepare it, a very dilute solution (containing 1½ to 2 per cent.) of hydrochlorate of harmine is heated to boiling; 10 to 15 per cent. of strong hydrochloric acid is then added to it, and afterwards, the solution being still kept boiling, chlorate of potassium is thrown in, by small quantities at a time, until the brownish red colour which the liquid assumes at first, is changed to pure yellow. The ebullition is maintained a little while longer, so as to destroy a coloured product; the solution is then allowed to cool; and the crystals of dichlorharmine which separate are washed with dilute hydrochloric acid, or with solution of chloride of sodium, and purified by crystallisation from alcohol, or re-solution in water and precipitation by hydrochloric or nitric acid. On redissolving the hydrochlorate of dichlorharmine in a large quantity of hot water, and boiling it for several hours with a great excess of soda-ley, crystals of dichlorharmine are deposited, which must be recrystallised from alcohol.

Dichlorharmine forms soft white needles, insoluble in cold, very slightly soluble in boiling water. It dissolves in *alcohol*, *ether*, *benzene*, and *sulphide of carbon*, much more easily when heated than in the cold.

Dichlorharmine forms a compound with *iodine*, corresponding to di-iodide of nitroharmine (p. 11), and containing 46·45 per cent. iodine.

With *acids* it forms crystallisable salts, which, like those of harmine, are very difficultly soluble in water containing acids or salts. The mono-acid (neutral) salts are decomposed to a certain extent, with separation of dichlorharmine, when a large quantity of water is poured upon them. Ammonia throws down dichlorharmine from their solutions, as an amorphous, colourless jelly; solution of soda acts in the same way, but in this case the precipitate becomes crystalline when long boiled with a great excess of soda solution. Dichlorharmine displaces a trace of ammonia from a boiling solution of sal-ammoniac; part of the dissolved dichlorharmine separates out on cooling, the rest only on addition of ammonia to the filtrate.

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Hydrochlorate of Dichlorharmine is obtained by dissolving the base in water containing hydrochloric acid, and precipitating by excess of hydrochloric acid. It crystallises from water in needles, from alcohol in larger crystals; chloride of sodium separates it from its solution in the form of a jelly which turns to needle-shaped crystals. It contains 2 at. water, which it gives off at 100° C., but reabsorbs 1 at. if exposed to moist air. When heated much above 100°, it becomes yellow and loses hydrochloric acid; between 180° and 200° it melts to a brown-yellow liquid, which dissolves in water and contains a newly formed base.

The *nitrate* is precipitated as a jelly, which afterwards changes to crystalline needles, by addition of excess of nitric acid to a solution of dichlorharmine in water containing nitric acid. It is anhydrous and less soluble in water than the hydrochlorate. When melted it gives off acid vapours and yields a brown mass, from the solution of which in aqueous alkalis acids throw down brown flocks.

Nitrate of dichlorharmine precipitates from *oxide of argentammonium*, a pale greenish jelly, containing silver. When hydrochlorate of dichlorharmine is mixed with nitrate of silver, a jelly is precipitated, without formation of chloride of silver, but, on adding nitric acid to the jelly, chloride of silver is formed.

Nitroharmine. $C^{13}H^{11}(NO^2)N^2O$. *Nitroharmidine.* (Fritzsche, Petersb. Acad. Bull. xii. 33, 225; Ann. Ch. Pharm. lxviii. 328; xcii. 330.)—Produced by the action of nitric acid on harmaline or nitroharmaline. It does not appear to be formed by the action of nitric acid on harmine. To prepare it, 1 pt. of harmaline is dissolved in 2 pts. of water, and the requisite quantity of acetic acid, and to the solution 12 pts. of nitric acid of specific gravity 1·40 are added in a thin stream. A violent evolution of red vapours takes place; and if the liquid be kept in a state of ebullition till the action is over, then cooled quickly, and treated with excess of caustic alkali, nitroharmine is deposited in the form of a deep yellow precipitate, while a resinous matter, formed at the same time, remains in solution. The product is purified by converting it into a hydrochlorate, and decomposing that salt with ammonia. Nitroharmine forms yellow needles, tasteless, sparingly soluble in cold, more soluble in boiling water. From boiling alcohol it separates in deep yellow octahedrons, which soon change into needles. Ether dissolves it but sparingly. It dissolves in rock-oil and in coal-tar naphtha. Heated with a solution of sal-ammoniac, it slowly eliminates ammonia. It unites with iodine, but is decomposed by chlorine and bromine.

The salts of nitroharmine have a slightly bitter taste, and mostly crystallise in yellow needles. The *hydrochlorate*, $C^{13}H^{11}(NO^2)N^2O.HCl + 2H^2O$, obtained by adding hydrochloric acid in excess to a solution of the base in acetic acid, or in hot water acidulated with a few drops of hydrochloric acid, crystallises in slender needles, which may be purified by recrystallisation from boiling alcohol. The *chloroplatinate* is soluble and crystallises in needles.

The *neutral nitrate* is but sparingly soluble in water, still less in dilute nitric acid: hence nitric acid gradually precipitates nitroharmine from the solutions of its other salts. It crystallises in yellow needles, which, if left in the acid liquor, gradually change to granular and rhomboïdal crystals of a deeper yellow colour. There appears also to be a *basic nitrate*, somewhat more soluble in water.

The hydrocyanate does not appear to exist by itself, but a double compound of *hydrocyanate of nitroharmine and mercuric cyanide* is deposited in granular crystals when cyanide of mercury is added to a boiling solution of acetate of nitroharmine and the liquid left to cool.

The *hydroferrocyanate* and *hydroferricyanate* are obtained by precipitation, the former in brown microscopic prisms, the latter in yellow grains. The *sulphocyanate* forms nearly colourless needles, sparingly soluble in cold, more soluble in hot water.

Di-iodide of Nitroharmine, $C^{13}H^{11}(NO^2)N^2O.I^2$, separates in yellowish brown agglomerated microscopic needles, on mixing the boiling solutions of iodine and nitroharmine in alcohol or coal-tar naphtha. It is nearly insoluble at ordinary temperatures in water, alcohol, ether, and coal-tar naphtha; slightly soluble at higher temperatures. It may be heated to 100° C. without decomposition. It is resolved into iodine and nitroharmine by boiling with alcohol, and more quickly with dilute sulphuric acid. It appears to form a crystalline salt with hydrochloric acid. It dissolves also in acetic and hydrocyanic acids, and these solutions yield crystalline compounds.

Bromonitroharmine. $C^{13}H^{10}BrN^3O^3 = C^{13}H^{10}Br(NO^2)N^2O$. *Bromonitroharmidine.*—When bromine-water is added to a very dilute solution of a salt of nitroharmine, the smell of bromine disappears immediately, and on addition of ammonia, bromonitroharmine is precipitated and may be purified by recrystallisation from alcohol. It resembles chloronitroharmine, forms salts with acids, and unites with bromine and iodine.

The *dibromide*, $C^{13}H^{10}BrN^3O^3.Br^2$, is formed on adding bromine-water in moderate excess to a solution of bromonitroharmine in weak alcohol, and separates on cooling and stirring the liquid, in yellow microscopic needles.

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CHLORONITROHARMINE. $C^{13}H^{10}ClN^3O^3 = C^{13}H^{10}Cl(NO^2)N^2O$. *Chloronitroharmidine.* (Fritzsche, Petersb. Acad. Bull. xii. 225; Ann. Ch. Pharm. xcii. 330).—Produced by the action of chlorine on nitroharmine, or of nitromuriatic acid on harmaline.

Preparation.—1. When chlorine-water is added to aqueous hydrochlorate or acetate of nitroharmine, or chlorine gas is passed into the solution till the smell of chlorine becomes permanent, chloronitroharmine separates in the form of a jelly. If the action of the chlorine be too long continued, a yellow resin is produced. The mixture is heated to boiling, and the resulting solution is precipitated by the cautious addition of ammonia, drop by drop, with constant stirring. A more or less crystalline product is thus obtained, whereas, from cold solutions, a jelly is precipitated, which is difficult to wash.—2. A solution of 1 pt. harmaline in 2 pts. water and the requisite quantity of acetic acid, is poured into 12 pts. of boiling nitric acid of specific gravity 1·40, and 2 pts. of fuming hydrochloric acid are added to the mixture; or the harmaline solution is poured into the boiling mixture of the two acids. The liquid becomes red-brown, froths up strongly, and evolves a volatile substance which attacks the eyes, but deposits nothing but resin on cooling. In order to separate the dissolved chloronitroharmine, a solution of sal-ammoniac, cooled by placing lumps of ice in it, is poured into the liquid; this is diluted with about an equal bulk of water; and caustic soda is then added, until it smells strongly of ammonia, whereby an abundant precipitate of impure chloronitroharmine is thrown down. The product is washed with dilute hydrochloric acid and heated with water; the solution freed by filtration from undissolved resin, and precipitated by gradual addition of ammonia; and the precipitate purified by crystallisation from hot alcohol. The crude chloronitroharmine may also be dissolved in boiling water, with addition of just the necessary quantity of nitric acid, and precipitated as nitrate from the cooled filtrate by addition of nitric acid in excess; this salt, after being washed, may be dissolved in hot water, and pure chloronitroharmine precipitated from the boiling filtered solution by means of caustic ammonia.

Chloronitroharmine forms a bright yellow, brittle mass, composed of very fine needles, which cannot be distinctly perceived, even under a magnifying power of 300. Ammonia precipitates it from cold solutions, as an almost transparent, deep yellow, very bulky jelly, which shrinks very much on drying. It is tasteless in the solid state, slightly bitter and rough in solution. It gives off 11·4 per cent. water at 100° C. (2 at. = 10·98 per cent.), and becomes orange-yellow. It dissolves but slightly in cold *water;* more abundantly in boiling water, forming a yellow solution; with moderate facility in boiling alcohol; slightly in ether; abundantly in boiling coal-tar naphtha, and in rock-oil.

Chloronitroharmine dried at 100° C. leaves a reddish-yellow residue when alcohol or coal-tar naphtha is poured upon it, but dissolves completely when boiled with dilute nitric acid.—*Solution of iodine* converts it into di-iodide of chloronitroharmine. When mixed with solution of iodide of potassium, and then with nitric acid, it deposits a deep blue precipitate.

Chloronitroharmine unites with acids, forming yellow salts. When boiled with solution of sal-ammoniac, it slowly displaces a trace of ammonia.

The *hydrochlorate*, obtained by adding hydrochloric acid in excess to a solution of the base in hot alcohol, forms fine capillary crystals moderately soluble in water. It is precipitated from its aqueous solution by a large excess of hydrochloric acid, as a yellow jelly; by chloride of sodium in white flocks. On mixing the hot alcoholic solutions of this salt and tetrachloride of platinum, *chloroplatinate of chloronitroharmine*, $2(C^{13}H^{10}ClN^3O^3.HCl)PtCl^4$, is deposited on cooling in fine yellow prisms.

The *nitrate* forms stellate groups of slender needles. A perfectly neutral solution of this salt mixed with ammonio-nitrate of silver, yields a precipitate consisting of a compound of chloronitroharmine with nitrate of silver.

Sulphates.—A solution of chloronitroharmine in warm alcohol containing sulphuric acid deposits the *neutral sulphate* on cooling, in spherical groups of capillary needles. From a hot aqueous solution the salt is deposited in light yellow gelatinous flocks. The *acid sulphate* separates slowly in needles from a hot concentrated alcoholic solution of the neutral salt mixed with excess of sulphuric acid.

Di-iodide of Chloronitroharmine, $C^{13}H^{10}ClN^3O^3.I^2$, separates in slender needles resembling di-iodide of nitroharmine, from a mixture of the hot solutions of iodine and chloronitroharmine in alcohol or in coal-tar naphtha. It is more soluble in alcohol than the di-iodide of nitroharmine, and dissolves easily in warm alcoholic hydrocyanic acid, separating in rounded granules on cooling.

HARMOTOME. This term includes two isomorphous mineral species, identical in crystalline form, viz.: *Baryta-harmotome*, and *Lime-harmotome.*

Baryta-harmotome, also called *Cross-stone, Staurolite, Andreolite, Andreasbergolite, Morvenite.*—Crystals belonging to the trimetric system, being generally

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rectangular prisms with four-sided summits set upon the lateral edges. Ordinary combination, P . $\infty\breve{P}\infty$. $\infty\bar{P}\infty$. $\bar{P}\infty$ (like *fig.* 528), often without $\bar{P}\infty$. Ratio of the axes: $a : b : c = 0{\cdot}9781 : 1 : 0{\cdot}684$. For P, the angle of the terminal edges in the brachydiagonal section = 121° 28′, in the macrodiagonal section, = 120° 1′; and the angle of the lateral edges (in a section parallel to the base) is 88° 44′. Cleavage most distinct parallel to $\infty\bar{P}\infty$. The crystals are generally twins, inserted crosswise into

Fig. 528.

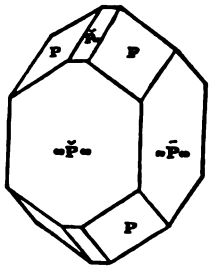
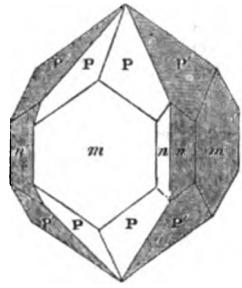


Fig. 529.



one another, as shown in *fig.* 529, in which the faces $\infty\breve{P}\infty$ are denoted by *n*, and $\infty\bar{P}\infty$ by *m*. For distinctness, the faces of one of the crystals are shaded (Kopp, *Krystallographie*, p. 263). Rarely massive. Specific gravity = 2·39 to 2·498. Hardness = 4·5. Lustre vitreous. Colour white, passing into grey, yellow, red, or brown. Streak white. Subtransparent to translucent. Fracture uneven, imperfectly conchoïdal. Brittle. Melts without intumescence before the blowpipe, forming a white globule. When finely pounded it is decomposed completely, though with difficulty, by hydrochloric acid.

The following are analyses of baryta-harmotome:—*a*, from Oberstein; *b*, from Strontian (Köhler, Pogg. Ann. xxxvii. 561); *c*, from Strontian (Connell, Ed. N. Phil. J., 1832, July, p. 33); *d*, *Morvenite*, from the same (Damour, Ann. Min. [4] ix. 339); *e*, from Andreasberg; *f*, from Strontian (Rammelsberg, *Mineralchemie*, p. 821).

	a.	*b.*	*c.*	*d.*	*e.*	*f.*
SiO^2	46·65	46·10	47·04	47·60	48·74	48·49
Al^2O^3	16·54	16·41	15·24	16·39	17·65	16·35
Fe^2O^3	. .	. .	0·24	0·65		
BaO	19·12	20·81	20·85	20·86	19·22	20·08
CaO	1·10	0·63	0·10			
K^2O }	1·10	0·90	1·72	1·55	. .	2·07
Na^2O }						
H^2O	15·25	15·11	14·92	14·16	14·66	13·00
	99·76	99·96	100·11	101·21	100·27	99·99

These analyses agree pretty nearly with the formula $BaO.Al^2O^3.5SiO^2 + 5H^2O$ (Rammelsberg), which requires 46·65 per cent. silica, 15·56 alumina, 23·79 baryta, and 14·00 water (the other constituents being regarded as adventitious), and by substituting $al = \frac{2}{3}$ Al. and regarding 2 at. hydrogen as basic, this formula becomes $(Ba''al^2H^2)Si^5O^{15}.4H^2O$, which is reducible to $\dot{M}^2SiO^3.\frac{2}{3}H^2O$, the formula of a metasilicate.

The composition of the mineral has, however, been hitherto generally represented by the formula $BaO.Al^2O^3.3SiO^3 + 5HO$, or $2(BaO.Al^2O^3).9SiO^2 + 10H^2O$; but this formula gives only 44 per cent. silica, which is considerably below that of all analyses which have been made of the mineral.

Baryta-harmotome occurs at Oberstein in Zweibrücken, in siliceous geodes; at Andreasberg in the Hartz; at Strontian in Argyleshire; in Norway on gneiss; and in simple crystals with analcime, in the amygdaloïd of Dumbartonshire. The variety called *Morvenite*, distinguished by the greater brilliancy of its crystals, is also found at Strontian. (Dana, ii. 323; Gm. iii. 446.)

Lime-harmotome or *Potash-harmotome*, *Phillipsite*, *Christianite*.—Isomorphous with the preceding, occurring also in twins. Specific gravity = 2·2 to 2·213. Hardness = 4 to 4·5. Lustre vitreous. Colour white, sometimes reddish. Streak uncoloured. Translucent—opaque. Before the blowpipe it intumesces slightly, gives off water, and melts to a translucent glass. Hydrochloric acid decomposes it easily, with separation of gelatinous silica.

The following are analyses of lime-harmotome:—*a*, from Annerode near Giessen

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(Wernekink, Gilb. Ann. lxxvi. 171, 336); *b*, from Stempel near Marburg (L. Gmel Leonh. Zeitschr. f. Min. 1826, i. 8); *c*, from the same; *d*, from Habichtswalde, n Cassel (Köhler, Pogg. Ann. xxxvii. 561); *e*, from the Giant's Causeway (Conne Edinb. Phil. J. xxxv. 373).

	a.	*b.*	*c.*	*d.*	*e.*	
SiO^2	48·36	48·51	50·44	48·22	47·35	
Al^2O^3	20·00	21·76	21·78	23·33	21·80	
Fe^2O^3	0·41	0·99	. .	. .	3·70	
CaO	5·91	6·26	6·50	7·22	4·85	
K^2O	6·41	6·33	3·95	3·89	5·55	Na^2O
BaO	0·46					
H^2O	17·09	17·23	16·81	17·56	16·96	
	98·64	101·08	99·48	100·22	100·21	

The composition of lime-harmotome has been represented by several different formu The quantities of calcium and potassium contained in it are somewhat variable, but composition appears to be, for the most part, that which is expressed by the form $\left.\begin{matrix}2CaO\\K^2O\end{matrix}\right\}.3Al^2O^3.12SiO^2+15H^2O$ (50·2 per cent. SiO^2, 21·3 Al^2O^3, 7·0 CaO, 6·5 K^2O, a 15·0 water), which, by substitution of *al* for $\frac{2}{3}$Al, as before, becomes $(Ca^2K^2al^6)Si^{12}O$ $15H^2O$, and is reducible to the general formula $M^{24}Si^{12}O^{36}.15H^2O$, or $M^2SiO^3.\frac{5}{6}H^2$ which is that of a metasilicate, and differs from the general formula of baryta-harm tome only in its amount of water.

Lime-harmotome occurs in the amygdaloïd of the Giant's Causeway, in large tra parent crystals. It is also found in Iceland; among the Vesuvian lavas; in sheaf-li aggregations at Capo di Bove, near Rome; and in long radiating crystals at Aci Caste in Sicily, and other localities. (Dana, ii. 324; Rammelsberg, *Mineralchemie*, p. 81

HARRINGTONITE. See NATROLITE.

HARRISITE. A variety of cuprous sulphide, Cu^2S, occurring in the Cant mine, Georgia, in crystals belonging to the regular system, and cleaving parallel to t faces of a cube (Shepard, Jahresb. f. Chem. 1857, p. 656). Genth (Sill. Am. J. [xxii. 449) regards it as a pseudomorph of copper-glance after galena.

HARTIN. $C^{16}H^{17}O$. *Psatyrin.*—A fossil resin resembling hartite. Massive, l crystallises from rock-oil in needles belonging to the trimetric system. White; des tute of taste and smell. Pulverises between the fingers. Melts at 210° C., and dist at 260°. Slightly soluble in ether. Gives, by analysis, 78·06 per cent. C, 10·92 and 11·02 O. It is found in the lignite of Oberhart, Austria. (Schrötter, Pogg. An liv. 45.)

HARTITE. C^3H^2.—Another fossil resin from the lignite of Oberhart. Obliq prisms belonging to the monoclinic system. Cleavage only in traces. Specific gravi 1·046. Hardness = 1. White, with a somewhat greasy lustre. Translucent. Britt Melts at 74° C., and distils at higher temperatures. Dissolves easily in ether, l readily in alcohol, and crystallises from each solution by evaporation (Haidinge Pogg. Ann. liv. 261). Gives, by analysis, 87·47 per cent. C and 12·05 H. (Schrötte

HATCHETTIN or *Mineral Tallow*, a fossil resin occurring in the coal measu of Glamorganshire; crystallised and amorphous in thin laminæ; like wax or sperm ceti in consistence. Specific gravity 0·916 at 15·5° C. White and transparent, wi nacreous lustre, but becomes black and opaque by long exposure. Greasy to the touc Melts at 46° C. Distils without change when cautiously heated. Dissolves sparing in boiling alcohol, and separates on cooling; sparingly also in cold ether, more eas in hot ether. Gives, by analysis, 85·9 per cent. carbon and 14·6 hydrogen (= 100·5 (Johnston, Phil. Mag. xii. 338.)

A similar substance is found at Rossitz, in Moravia. Specific gravity, 0·892. Har ness = 1. A variety from Loch Fyne, near Inverness, melts at 47° C. Another alli mineral from Merthyr Tydvil, melts at 76·6° C.

HAUERITE. Native disulphide of manganese, MnS^2, found at Kalinka, in Hu gary. (See MANGANESE, SULPHIDES OF.)

HAUSMANNITE. Native manganoso-manganic oxide, $MnO.Mn^2O^3$, or Mn^3O found at Ilmenau in Thuringia, at Ihlefeld in the Hartz, and one or two other local ties. (See MANGANESE, OXIDES OF.)

HAUYNE. A mineral consisting of silicate of aluminium, sodium, and calciu with sulphate of calcium, occurring in the lavas of Vesuvius, on Somma, and on t basalt of Niedermendig, near Andernach, on the Rhine. It crystallises in rhomb dodecahedrons, with cleavage parallel to the faces, sometimes distinct; commonly i

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crystalline grains. Specific gravity 2·4 to 2·5. Hardness 5·5. Lustre varying from vitreous to greasy. Colour bright blue, occasionally asparagus-green. Streak bluish-white. Subtransparent to translucent. Fracture flat-conchoïdal to uneven. Before the blowpipe it decrepitates and fuses slowly to an opaque white or greenish-blue glass. Effervesces with borax, and forms a glass which is yellow when cold. The finely pulverised mineral dissolves completely in hydrochloric acid, the liquid depositing gelatinous silica when evaporated.

The composition of hauyne has been variously stated. From the analysis of the mineral from Mont Albano, Whitney (Pogg. Ann. lxx. 431) deduced the formula $3(Na^2O.Al^2O^3.2SiO^2) + 2(CaO.SO^3)$, or $3(Na_2^{al})SiO^4.CaSO^4$; from that of hauyne from Somma, Rammelsberg calculates the formula $2(Na^2O.Al^2O^3.2SiO^2) + (CaO.SO^3)$, or $4(Na_2^{al})SiO^4.CaSO^4$. The following table exhibits the numbers deduced from these formulæ, together with the results of the corresponding analyses:

Mont Albano.	(Whitney.) Calc.	Analysis.	*Somma.*	(Rammelsberg.) Calc.	Analysis.
$6SiO^2$ . .	32·20	32·48	$4SiO^2$ . .	34·29	34·06
$2SO^3$ . .	14·31	12·98	SO^3 . .	11·43	11·25
$3Al^2O^3$ . .	26·83	27·75	$2Al^2O^3$ . .	28·57	27·64
2CaO . .	10·02	9·96	CaO . .	8·00	10·60
$3Na^2O$ . .	16·64	14·24	$2Na^2O$ . .	17·71	11·79
K^2O . .	. .	2·40	K^2O . .	. .	4·96
	100·00	99·81		100·00	100·30

According to these formulæ, hauyne is allied to nosean, sodalite, and ittnerite, all of which are silicates of the form $M^2O.Al^2O^3.2SiO^2$, easily reducible to an orthosilicate, $(Ma_2^{al})SiO^4$ [$a' = \frac{1}{3}Al = 9·1$]. The formulæ of these minerals are in fact:

Hauyne: $\left.\begin{matrix}3\\ \text{or } 4\end{matrix}\right\} Ma_2^{al}SiO^4 . CaSO^4$

Sodalite: $3Ma_2^{al}SiO^4 . NaCl$

Nosean: $6Ma_2^{al}SiO^4 . Na^2SO^4$

Ittnerite: $6Ma_2^{al}SiO^4 . (CaSO^4; NaCl) + 6H^2O$

Hauyne from Niedermendig contains, according to Whitney, 33·90 SiO^2; 12·01 SO^3; 28·07 Al^2O^3; 7·50 CaO and 19·28 Na^2O = 100·73, and is composed of 1 molecule of nosean and 2 molecules of the Albano hauyne. The blue colour of hauyne appears to arise from a small quantity of a metallic sulphide similar to that which gives the colour to ultramarine. All specimens of hauyne, when treated with hydrochloric acid, give off at least a trace of sulphydric acid. (Dana, ii. 230; Handw. d. Chem. iii. 832.)

HAUYNOPHYR. A name applied to the lava of Melfi on the Vulturo. This lava is black or brown, and contains hauyne of various colours, and augite in slender needles. It is strongly attacked by acids. When it is treated with an equal weight of a mixture of 2 pts. hydrochloric acid and 1 pt. water, 30·2 per cent. remains undecomposed, consisting mainly of augite containing a large proportion of iron. The hauyne amounts to 22 per cent. (Rammelsberg, Jahresb. 1860, p. 807.)

HAYDENITE. Yellowish chabasite, from Jones's Falls, Maryland. (See CHABASITE.)

HAYESINE. (Syn. with BOROCALCITE.)

HAYTORITE. Pseudomorphous quartz, from the mine of magnetic iron at Hay Tor, in Devonshire. It has the form of datholite, and contains 98·5 per cent. silica and 0·2 ferric oxide.

HEAT. The word Heat is used in common language, both as the name of a particular kind of sensation, and to denote that condition of matter in which it is capable of producing this sensation in us. Any influence whereby external objects are rendered *hot*, or capable of exciting the sensation of heat, causes them at the same time to undergo other changes, which, being independent of the varying condition of our bodies, afford much more certain and more exact indications as to the condition of heat than is furnished by the sense of touch. Indeed, strictly speaking, our sensations bear no direct testimony with regard to the absolute degree of hotness of external objects, but rather to the fact of their imparting heat to our bodies, or removing heat from them. When these effects are produced in a moderate degree, we experience the sensations of heat and cold respectively; when the loss or gain of heat by our bodies is more rapid, it no longer produces any sensation to which a definite name can be assigned, but simply a feeling of pain; and the very rapid passage of heat either into or out of our bodies, causes a wound which is of the same kind in either case. The direct evidence of our senses with respect to the heat of external objects is therefore confined within comparatively narrow limits. Moreover, it is not always of the same

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kind, even with respect to bodies in the same condition, as is easily proved by p one hand into hot water and the other into cold water, and after a short time i ing both and plunging them into lukewarm water, which will then feel cold to th which was previously in hot water, but warm to the other.

The most important of the other properties of the condition of matter consti heat, besides producing the sensation denoted by the same word, are the followi

1. Heat imparted to any body raises its *temperature*, that is, it not only caus body to produce the sensation of heat in a more marked degree, but its tende impart the property of so doing—in other words, its tendency to impart heat—to bodies is increased.

2. It modifies the relations between the density and elasticity of substanc general law being, that the hotter a body is, the less is its *elasticity of figure*, or ency to preserve a definite form and arrangement of parts, and the greater is its *ela of volume*, or tendency, if solid or liquid, to preserve a definite volume, and if g to expand indefinitely.

3. Heat causes solid bodies to become liquid, and liquid bodies to become ga The amount of heat required to produce these changes in any body varies wi special nature and with other circumstances, but they take place always and w exception, in the same order; that is, the solid state always corresponds to the l degree of heat, the gaseous state to the highest degree, and the liquid state intermediate degree.

4. Heat causes changes in the chemical composition of bodies, and also in electrical, magnetic, and optical properties.

The capacity of heat thus to effect changes characterises it as a form of en capable of being measured and expressed as a quantity, in terms of one or other c directly measurable effects which it produces. When thus expressed as a qua the condition of heat is found to be subject, like other forms of energy (mech energy, for example), to a law of conservation; that is, if in any system of b no heat is expended or produced through changes other than changes of temper then the total quantity of heat in the system cannot be changed by the mutual a of the bodies, but what one loses another gains; and if there are changes other changes of temperature, then if by those changes the total heat of the system is ch in amount, that change is compensated exactly by an opposite change in some other of energy. (See Rankine, *A Manual of the Steam Engine and other Prime M* ed. 1861, § 196, pp. 224, 225.)

Hence it follows that heat may be produced by the reversal of its effects: a instance, by the conversion of a liquid body into a solid, or of a gas into a liquid the compression of a gas, so as to make it occupy a smaller bulk; by the transmi through the point of junction of two dissimilar metals, of an electric current opp in direction to that which would be produced by the application of heat at the point; by the union of oxygen and hydrogen so as to form water, the effect of upon water being to resolve it into oxygen and hydrogen gases, &c. &c.

Similarly, heat may be caused to disappear—in other words, cold may be produc when a change, such as heat is capable of producing, is brought about by other me as when a solid is liquefied by solution, or when a liquid is vaporised; when a g expanded; when, through the point of junction of two dissimilar metals, an ele current is transmitted in the same direction as that which would be produced b application of heat at the same point, &c. &c.

The reversal of any of its effects does not, however, necessarily and under all cumstances, cause heat to be produced: instead of it an equivalent of some other for energy may be generated; thus, in Grove's gas-battery (Electricity, ii. 430) the pri result of the combination of oxygen and hydrogen gases is not the evolution of quantity of heat which would be required to decompose the water formed, but o equivalent amount of electrical energy. Neither is the disappearance of heat alw a necessary consequence of the production, by other means, of changes such as m be brought about by the action of heat itself: for example, in the decompositic water by the electric current, there is no disappearance of heat, but there is exper an amount of electrical energy, equivalent to the heat which would otherwise h been required to effect the same decomposition. Further, the most familiar and r practically important processes by which heat is produced, such as combustion, fric and percussion, are not such as can be directly reversed by the action of heat.

On the other hand, heat being a form of energy, every source or store of en may be considered as, directly or indirectly, a source of heat. The sources of h available to man may therefore be classified as follows:

1. The *Sun*. According to Pouillet, the total heating effect of the sun's rays f ing perpendicularly during 1 minute upon one square centimetre of the earth's surf including the portion absorbed by the atmosphere, amounts to 1·7633 times the qu

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tity of heat required to raise the temperature of 1 grm. of water 1 degree centigrade, or to 1·7633 gramme-degrees. The mean heating effect on each square centimetre of the earth's surface, for every minute during 24 hours, is therefore = 0·4408 gramme-degree; or the total effect during one year is 232,000 gramme-degrees.* According to these data, the whole quantity of heat received by the earth from the sun in one year would be sufficient to melt a layer of ice over the whole surface of the earth of 32 metres (or 35 yards) in thickness. The whole of this supply of heat (which is less than the 2,300 millionth part of the total heat emitted by the sun) is not, however, directly available as such. According to Pouillet, nearly one-half is absorbed by the atmosphere, and of the heat so absorbed a considerable proportion goes to supply the mechanical energy of air in motion, or wind, and thus ceases, at least for a time, to exist as heat. Another portion is expended in causing the evaporation of water from the ocean and from the moist surface of the land: as will be shown in the sequel, a great part of this heat reappears when the evaporated water is returned to the earth as rain or otherwise; but the remainder is retained in a modified form in water which is deposited at a higher level than that from which it was evaporated, and so furnishes the mechanical energy, or water-power, of rivers and falling water. Still another portion of the total energy of the sun's rays is absorbed by growing plants, enabling them to convert carbonic acid and water into woody fibre: our ordinary modes of obtaining artificial heat—namely, by the combustion of wood and coal—are processes in which the heat thus absorbed is liberated by the reversal of the chemical changes which take place in plants while living. The warmth and mechanical force of animals are also derived, through the vegetable food which they consume, from the same source, whence are likewise derived, directly or indirectly, our chief supplies of electrical energy.

2. The *internal heat* of the earth. This we may consider as of two kinds: the actual heat, of which there is evidence in hot springs and volcanoes, as well as in the comparatively high temperature of deep mines; and the potential heat stored up in combustible minerals. By far the most important store of potential heat, namely, coal, represents, as we have already seen, a portion of the energy of the sun's rays which reached the earth during the growth of the plants from which it has been formed.

3. The *tidal wave*, caused by the earth's diurnal rotation, combined with the mutual motions of the earth, moon, and sun, is a source of heat which might be rendered practically available, by causing water-wheels, driven by the tidal waters, to generate heat by friction.

4. The *fall of meteoric stones* is a source of heat, practically insignificant, so far as the earth is concerned, but which has been supposed to play an important part in the maintenance of the heat of the sun.

(On the possible sources of energy available to man, see W. Thomson, Phil. Mag. [4] iv. 259.)

On the Measurement of Heat.

Before we can proceed further in the study of the properties and effects of heat, it is necessary that we should have some means of measuring and comparing different quantities of it. As already stated, quantities of heat may be expressed in terms of any of its directly measurable effects; but that one which is usually the most easily and accurately observable is alteration of temperature, and hence quantities of heat are commonly defined by stating the extent to which they are capable of altering the temperature of a known weight (such as 1 grm.) of a known substance (for instance, water). Accordingly, the unit of heat which will be employed in this article is the quantity, already spoken of as a gramme-degree, which is required to raise the temperature of 1 gramme of water from 0° to 1° centigrade. Heat is, however, capable of causing other alterations in the condition of bodies, such as the liquefaction of solid substances, without at the same time causing any alteration in their temperature; hence, another way in which a quantity of heat may be defined is by stating the amount of some known solid (ice, for example) which it is capable of liquefying, without causing any change in its temperature. Quantities of heat can also be expressed in terms of the mechanical or electrical energy to which they are equivalent; but as neither motion nor electricity can be generated by heat without the simultaneous expenditure of a greater or less quantity in causing a rise of

* The total quantity of heat received in a minute by a hemisphere of the earth's surface is the same as that which would fall on the great circle forming the projection of that hemisphere—that is to say, $1{\cdot}7633\ \pi R^2$ gramme-degrees (the radius being measured in centimetres). Hence, supposing the heat to be uniformly distributed over this surface, the quantity received in a minute by each square centimetre of surface is

$$\frac{1{\cdot}7633\ \pi R^2}{4\pi R^2} = 0{\cdot}4408 \text{ gramme-degrees;}$$

and as the earth performs its rotation in 24 hours and the year contains 365 days, it follows that the mean amount of heat received in a year by each square centimetre of the earth's surface is 0·4408 × 60 × 24 × 365, or in round numbers, 232,000 gramme degrees.

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temperature in material substances, and since, therefore, the whole of a given q can never be transformed without loss into these other forms of energy, they serve for the direct measurement of heat. And in fact, whatever mode of measu is adopted, it is always necessary to take account of the temperature of the whose heat is to be estimated, and of those which are influenced by them, i that we may know the extent to which their temperature is altered; or on th hand, that we may convince ourselves that no such alteration takes place. Th surement of temperature, or *thermometry*, is therefore a necessary preliminary measurement of heat, or *calorimetry*.

Thermometry.—Temperature, or hotness, has already been defined as the te of one portion of matter to part with heat to other portions, and has been st depend on the quantity of heat which the portion of matter in question contain the purpose of defining different temperatures, it is obviously necessary to ad standard points, separated by a known and constant interval, which may ser measure by which to estimate the interval between any other two temperatures standard points usually adopted are the temperature of melting ice, and th perature of pure water boiling freely under a barometric pressure of 760 mill (= 29·92 inches) of mercury (measured at the melting point of ice). When tity of mercury is allowed to attain equilibrium of temperature with melting i afterwards with water boiling under the conditions above mentioned, it is fou its bulk in the latter case always exceeds its bulk in the former case by a certain c amount. The expansion of the mercury is here a measure of the quantity which the boiling water imparted to it after it had come to such a condition interchange of heat no longer took place between it and the melting ice; and s already observed, the mercury always expands by the same proportion of its bull temperature of melting ice, we may conclude that the quantity of heat which water can impart to a given mass of matter, exceeds that which melting ice can to the same mass, by a constant proportion; in other words, that the temper boiling water is higher than the temperature of melting ice, and that the interva separates them is always the same.

It is upon this principle that the use of the mercurial thermometer, and o instruments in which expansion is employed to indicate temperature, depends construction and use of this instrument in its various forms are fully described article THERMOMETER, to which the reader is referred. It will be sufficient state, that there are in frequent use three different modes of designating t standard points of temperature, and of subdividing the interval between them: the *centigrade* scale of Celsius employed in this Dictionary, in which the temp of melting ice is denoted by zero, and the temperature of boiling water b Réaumur's scale, in which the temperature of melting ice is likewise denc zero, but that of boiling water by 80; and Fahrenheit's scale, in which the temperature is marked 32, and the latter 212. The melting point of ice is th indicated by any of the following expressions:—

0° C., 0° R., and 32° F.;

and the boiling point of water by any of the following:—

100° C., 80° R., and 212° F.;

accordingly, 100 degrees centigrade are equivalent to 80 degrees Réaumur, and (= 212 − 32) degrees Fahrenheit, or 5 degrees C. = 4 degrees R. = 9 degrees F simplicity of these relations makes it easy, when a temperature is expressed ac to any of the three scales, to find an equivalent expression according to either other two. (See further the article THERMOMETER.)

Besides the mercurial thermometer, and the spirit thermometer, which is quite to it in principle and in the manner in which it is used, there are some other ments, which are advantageously employed in special cases, for the measuren temperature, and must therefore be briefly described here.

The *Weight-thermometer*.—This is a mercurial thermometer which differs fr common one, inasmuch as the expansion of the mercury consequent upon rise o perature is not read off directly from a divided scale, but is calculated from the of mercury which escapes from the instrument. It consists of a cylindrical glass voir, closed at one end, and terminated at the other by a short capillary glas which is so bent that, when the thermometer is placed in the position in which be used, its open end points vertically downwards. The mode of using it is as fo The thermometer is weighed while empty, and the reservoir and tube are ther pletely filled with pure mercury, the whole of the air being carefully expelled by b and allowing the instrument to cool while the open end of the capillary tube dips the surface of mercury, as in the usual process of filling a barometer or thermo

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By surrounding the thermometer with melting ice, the instrument itself, as well as the mercury contained in it, is brought to the temperature of 0° C.: when this temperature has been reached by every part of it, the vessel of mercury is removed from under the open end of the capillary tube, and is replaced by a small tared capsule. The ice is now removed, and the outside of the thermometer is carefully dried. As the mercury contained in it returns to the temperature of the air (supposed above 0° C.), it expands, and, consequently, some of it escapes by the capillary tube into the tared capsule. The thermometer, and the capsule containing the mercury which has escaped from it, are now placed together in the balance and weighed; by deducting from the gross weight so obtained the weight of the instrument when empty, and that of the capsule, we obtain the weight W, of the quantity of mercury which fills the thermometer at 0° C.

The instrument is next heated to 100° C., by immersing it in the steam of boiling water, the same precautions being taken as in fixing the boiling point of the ordinary graduated thermometer (see THERMOMETER), and the mercury which escapes is collected in the tared capsule and weighed. Let w be the weight of the whole quantity of mercury which escapes from the thermometer when it is heated from 0° C. to 100° C.; then the coefficient of apparent expansion (see below, *Expansion of Liquids*) of the mercury contained in the thermometer will be

$$\delta = \frac{w}{(W - w)100} \quad . \quad . \quad . \quad . \quad . \quad . \quad (a)$$

Similarly, if w_t be the weight of mercury which escapes from the thermometer when it is heated to any other temperature, $t°$, which it is required to determine, we have

$$\delta = \frac{w_t}{(W - w_t)t}; \quad . \quad . \quad . \quad . \quad . \quad . \quad (b)$$

hence we get

$$\frac{w_t}{(W - w_t)t} = \frac{w}{(W - w)100},$$

or—

$$t = \frac{w_t}{w} \cdot \frac{W - w}{W - w_t} \times 100$$

The value of δ, deducible from equation (a), was found by Dulong and Petit (who were the first to employ the weight-thermometer) to be equal to $\frac{1}{5.5.5.5}$, and by substituting this value in equation (b) the value of t is given independently of the preliminary experiment above described, in which the thermometer is heated to 100° C.; but some uncertainty is thus introduced into the determination, inasmuch as the value of δ varies to a slight extent with the kind of glass of which the thermometer is made.

The weight-thermometer is capable of giving very accurate results when employed to indicate the mean temperature of any considerable space, such as an oil- or water-bath, the temperature of which changes so slowly that it may be assumed, at any given instant, to be the same as that of the thermometer. The size of the instrument depends upon the purpose for which it is to be employed: it is well that it should be of such a length as to reach from one end to the other of the space whose temperature has to be measured, and its capacity ought to be such that the weight of mercury driven out by the smallest rise of temperature which it is required to estimate may be capable of being accurately determined by the balance. An obvious precaution in the use of this instrument is to keep the open end constantly under the surface of the mercury in the capsule, so that no air can enter in consequence of a diminution of temperature.

Regnault's *Air-thermometer* is an instrument which is applicable in the same kind of cases as the weight-thermometer, but has the advantage of giving accurate results at all temperatures below that at which glass softens, whereas the indications of the weight-thermometer are obviously confined to temperatures below the boiling-point of mercury. In construction, it closely resembles the latter instrument, and consists of a cylindrical glass reservoir about 2 centimetres (0·8 inch) in diameter and about 12 or 15 centimetres (4·8 or 6 inches) long, terminated at one end by a narrow glass tube of 1 or 2 millimetres internal diameter, which is bent at a right angle, at a short distance from the end farthest from the reservoir, and drawn out to a fine point. In this state, the instrument is placed in the space of which it is desired to know the temperature; and as soon as the instant arrives for which this temperature is required, the drawn-out point is sealed by fusion with the blowpipe, the height of the barometer and its attached thermometer (i. 512) being observed at the same time. The thermometer thus closed is then supported in a vertical position, the narrow tube downwards, and with the bent and sealed extremity of the latter under the surface of mercury; it is next opened by breaking off, under the mercury, as small a piece as possible of the point; and the reservoir is completely surrounded with melting ice. Owing to the contraction of the air in the thermometer as it cools, the mercury rises in the tube and

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partially fills the reservoir; and, when the temperature of the thermometer and its contents has been reduced to 0° C., the height of the surface of the mercury in the reservoir, above that of the mercury outside the instrument, is measured by a cathetometer, the height of the barometer being carefully noted at the same time. The open end of the tube is now closed, while still under mercury, by pressing against it a pellet of soft wax; the ice is removed from the reservoir; and the instrument is taken out of the support, inverted, and weighed together with the mercury contained in it. The thermometer is next completely filled with mercury at 0° C. and weighed again, and lastly the weight of the instrument itself when empty is determined.

Let W be the weight of mercury which completely fills the thermometer, and let w be the difference between this weight and that of the mercury contained in it at the first weighing. These two weights then bear to each other the same proportion as the total capacity of the thermometer at 0° C. bears to the volume occupied—at 0° C. and under the atmospheric pressure diminished by the column of mercury read off by the cathetometer—by the air which the thermometer contained at the moment when it was sealed with the blowpipe. They may therefore be taken to represent respectively these volumes: we shall then have

$$W(1 + \kappa t) = w\frac{h}{H}(1 + \alpha t),$$

or—

$$t = \frac{W - w\frac{h}{H}}{w\frac{h}{H}\alpha - W\kappa};$$

where t is the temperature required;

H, the atmospheric pressure at the moment of sealing the thermometer with the blowpipe;

h, the pressure supported by the air in the thermometer at the moment of closing it with the pellet of wax = the barometric pressure observed at the same moment —the column of mercury read off with the cathetometer;

α, the coefficient of expansion of air for 1° C = 0·00366;

κ, the coefficient of cubical expansion of the glass of which the thermometer is made = 0·0000305, between 0° and 300° C., for common glass, and = 0·0000233 for crystal-glass from Choisy-le-Roi. (Regnault.)

(For the derivation of the above formula, see the section Expansion of Gases in this article; for further details of the air-thermometer, see Regnault, *Cours élémentaire de Chimie*, éd. 1854, iv. 64.)

Deville and Troost's *Iodine-pyrometer*.—For the measurement of temperatures above that at which glass softens, Deville and Troost employ a method which depends on essentially the same principles as the use of the air-thermometer, although the mode of experimenting differs considerably. Their apparatus consists of a globular flask of Bayeux porcelain of 280 or 300 c. c. capacity, with a neck 11 centimetres long and 4 mm. in internal diameter. A quantity of iodine is put into the flask, and the neck is nearly closed by a small plug of porcelain which lies loosely in the opening. When the flask is now exposed to a high temperature, the iodine is vaporised and the greater part escapes by the neck, driving out at the same time nearly the whole of the air. After the flask has been exposed for about twenty minutes to the temperature that is to be measured, the flame of an oxy-hydrogen blowpipe is allowed to play for an instant upon the porcelain plug lying in the neck: the plug is thus melted and closes the flask hermetically. When cold, the flask is cleaned and carefully weighed; the end of the neck is broken under boiled water or mercury, and the flask is weighed, together with the water or mercury which enters; it is then completely filled with water or mercury and weighed again; lastly, the flask is weighed when empty. From the weights thus obtained it is easy to calculate the capacity of the flask, and the volume of air which the iodine-vapour has failed to expel: the first weighing gives directly the excess of the weight of the flask and iodine-vapour over that of the empty flask. The observations which require to be made in each experiment are the following:—

Temperature of the balance	= $t°$
Atmospheric pressure	= h mm.
Excess of weight of flask after being heated and sealed full of iodine-vapour over weight of flask filled with air previous to the experiment	= i grm.
Capacity of flask	= v c. c.
Residual air	= a c. c.

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Besides these data, the following constants are required in order to calculate the temperature at which the flask was sealed:—

Weight of 1 c. c. air at 0° and 760 mm. pressure . .	= 0·001293 grm.
Density of iodine-vapour referred to air as unity . . .	= 8·716
Coefficient of expansion of air for 1° C.	0·00366
Coefficient of cubical expansion of Bayeux porcelain for 1° C.	= 0·0000108

The required temperature, T, can now be calculated as follows:

let $I_v \left(= \frac{(v-a)\cdot 001293}{1 + \cdot 00366t} \cdot \frac{h}{760} + i \right)$ be the total weight of iodine-vapour contained in the flask at the moment of sealing, then

$$\frac{I_v}{0{\cdot}001293 \times 8{\cdot}716} \cdot \frac{(1 + 0{\cdot}00366\ T)\ 760}{h} = I_v$$

will be the volume of this vapour at the same moment; but

$$I_v + \frac{a\,(1 + 0{\cdot}00366\ T)}{1 + 0{\cdot}00366t} \cdot \frac{760}{h} = v(1 + 0{\cdot}0000108\ T)$$

and from this equation, in which T is the only unknown quantity, its value is easily found.

It is obvious that this method is applicable only for the measurement of maximum temperatures which can be maintained stationary for some time; but in cases where these conditions can be fulfilled, as in determining the boiling points of difficulty volatile substances (*e.g.* sulphur, cadmium, zinc) it is capable of yielding very accurate results.

A porcelain globe filled with air may be employed as a thermometer in the same way: the advantage of using iodine is that given differences of temperature correspond to greater differences of weight.

(See further Deville and Troost, Ann. Ch. Phys. [3] lviii. 267, 275, 285, 293.)

Mercury-pyrometer.—This instrument, proposed by Regnault (Ann. Ch. Phys. [3] lxiii. 40), is composed of a bottle made of cast or wrought iron, platinum or porcelain, having a capacity of 500 to 1000 c. c., and provided with a perforated lid which lies flat upon the neck of the bottle, the under surface of the lid (which has a considerably greater diameter than the neck) and the upper surface of the neck being ground together, so that by sliding the lid a little to one side, the bottle can be almost completely closed without removing it from the furnace, or other space whose temperature is to be determined. Before beginning the experiment, 10 or 15 grms. of pure mercury are put into the bottle, and it is then placed in the furnace, the lid being laid on so that the hole through it forms a continuation of the orifice of the neck; when the bottle has been in the furnace long enough to have thoroughly assumed the temperature of the latter, it is closed by drawing the lid sideways, then removed from the furnace, and quickly cooled. The mercury remaining in the bottle is poured out (it can be completely detached from the bottle by shaking a little water round in it), and weighed, either in the metallic state, or, when necessary, after solution in an acid and precipitation. When the following data are known, namely—

- v = capacity of the bottle in c. c. at 0° C.;
- κ = coefficient of cubic expansion of the substance of the bottle;
- h = atmospheric pressure at the moment of withdrawing the bottle from the furnace;
- d = density of mercury-vapour at temperatures at which it has the properties of a perfect gas;
- p = weight of mercury remaining in the bottle;

the required temperature, T, can be calculated.

The weight of mercury-vapour which fills the bottle at $T°$ is

$$= v \cdot \frac{1 + \kappa T}{1 + 0{\cdot}00366\ T} \cdot 0{\cdot}0012932 \cdot d \cdot \frac{h}{760} = p;$$

hence

$$\frac{1 + \kappa T}{1 + 0{\cdot}00366\ T} = \frac{760}{v \cdot 0{\cdot}0012932 \cdot d} \cdot \frac{p}{h} = M \cdot \frac{p}{h},$$

in which last expression M is a quantity which remains constant for the same bottle: we have therefore

$$T = \frac{1 - M\,\frac{p}{h}}{M \cdot 0{\cdot}00366\,\frac{p}{h} - \kappa}$$

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Regnault's *Hydrogen-pyrometer* (Ann. Ch. Phys. [3] lxiii. 42) is an instrument whereby the temperature of a furnace or other heated space can be quickly determined at any required instant. It consists of a wrought iron tube one or two inches wide, and long enough to reach from one side of the furnace to the other, terminated at each end by a capillary tube of the same material, provided with a three-way cock. When the temperature of the furnace is to be determined, a current of pure and dry hydrogen is caused to enter the iron tube at one end, and allowed to issue freely into the air at the other; when the current of gas has been continued long enough to displace all the air, and to reduce any oxide that may have formed in the inside of the tube, it is stopped; the free end of the iron tube is connected with a copper tube filled with oxide of copper, and heated to redness by a row of gas-jets; the current of hydrogen is then replaced by a slow current of dry air, which sweeps forward the hydrogen into the copper tube, where it is completely converted into water. The water thus formed passes on to a weighed U-tube containing pumice-stone and sulphuric acid, and from its weight the temperature of the furnace can be calculated upon the same principle as when the mercury pyrometer is used. (For further details, and for figures of this apparatus and of that last described, see Regnault, *loc. cit.*)

The *Thermomultiplier*.—This instrument consists of a thermo-electric pile, connected with a delicate galvanometer; its construction, and the principles upon which its action depends, have already been explained in the article ELECTRICITY (ii. 413 and 443, 444). As a thermoscope, or instrument for rendering sensible heat of very low intensity, this apparatus is much more delicate than any other that has been devised, the heat given out by the human body producing a perceptible effect upon it, even at a distance of ten yards or more (Daguin, *Traité de Physique*, 2nd edit. ii. 34). As a differential thermometer, it is capable of giving accurate results, when the intervals of temperature to be measured are sufficiently small. But, since the direct indications of the instrument are not generally proportional to these intervals of temperature, it is necessary to construct, for each thermomultiplier, a table showing the interval of temperature to which each degree read off upon the instrument really corresponds. The following account of the method recommended by Melloni for constructing these tables is given by Tyndall (*Heat as a Mode of Motion*, p. 355), being translated by him from 'La Thermocrose,' p. 59:—

"Two small vessels are half-filled with mercury, and connected separately by two short wires, with the extremities of the galvanometer. The vessels and wires thus disposed make no change in the action of the instrument; the thermo-electric current being freely transmitted, as before, from the pile to the galvanometer. But if, by means of a wire, a communication be established between the two vessels, part of the current will pass through this wire and return to the pile. The quantity of electricity circulating in the galvanometer will be thus diminished, and with it the deflection of the needle.

"Suppose, then, that by this artifice we have reduced the galvanometric deviation to its fourth or fifth part; in other words, supposing that the needle being at 10 or 12 degrees, under the action of a constant source of heat, placed at a fixed distance from the pile, that it descends to 2 or 3 degrees when a portion of the current is diverted by the external wire; I say that by causing the source to act from various distances, and observing in each case the *total* deflection and the *reduced* deflection, we have all the data necessary to determine the ratio of the deflections of the needle, to the forces which produce these deflections.

"To render the exposition clearer, and to furnish, at the same time, an example of the mode of operation, I will take the numbers relating to the application of this method to one of my thermomultipliers.

"The external circuit being interrupted, and the source of heat being sufficiently distant from the pile to give a deflection not exceeding 5 degrees of the galvanometer, let the wire be placed so as to connect the two vessels of mercury; the needle falls to 1·5. The connection between the two vessels being again interrupted, let the source be brought near enough to obtain successively the deflections:—

$$5°,\ 10°,\ 15°,\ 20°,\ 25°,\ 30°,\ 35°,\ 40°,\ 45°.$$

Interposing after each the same wire, we obtain the following numbers:—

$$1{\cdot}5°,\ 3°,\ 4{\cdot}5°,\ 6{\cdot}3°,\ 8{\cdot}4°,\ 11{\cdot}2°,\ 15{\cdot}3°,\ 22{\cdot}4°,\ 29{\cdot}7°.$$

"Assuming the force necessary to cause the needle to describe each of the first degrees of the galvanometer to be equal to unity, we have the number 5 as the expression of the force corresponding to the first observation. The other forces are easily obtained by the proportion:—

$$1{\cdot}5 : 5 = a : x = \tfrac{5}{1{\cdot}5}\,a = 3{\cdot}333a,$$*

* That is to say, one reduced current is to the total current to which it corresponds, as any other reduced current is to its corresponding total current.

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where a represents the deflection when the exterior circuit is closed. We thus obtain

5, 10, 15·2, 21, 28, 37·3

for the forces corresponding to the deflections,

5°, 10°, 15°, 20°, 25°, 30°.

"In this instrument, therefore, the forces are sensibly proportional to the arcs up to nearly 15 degrees. Beyond this the proportionality ceases, and the divergence augments as the arcs increase in size.

"The forces belonging to the intermediate degrees are obtained with great ease, either by calculation or by graphical construction, which latter is sufficiently accurate for these determinations.

"By these means we find,

Degrees . .	13°	14°	15°	16°	17°	18°	19°	20°	21°
Forces . .	13	14·1	15·2	16·3	17·4	18·6	19·8	21	22·3
Differences . .		1·1	1·1	1·1	1·1	1·2	1·2	1·2	1·3
Degrees . .	22°	23°	24°	25°	26°	27°	28°	29°	30°
Forces . .	23·5	24·9	26·4	28	29·7	31·5	33·4	35·3	37·3
Differences . .		1·4	1·5	1·6	1·7	1·8	1·9	1·9	2

"In this table we do not take into account any of the degrees preceding the 13th, because the force corresponding to each of them possesses the same value as the deflection.

"The forces corresponding to the first thirty degrees being known, nothing is easier than to determine the values of the forces corresponding to 35, 40, 45 degrees, and upwards.

"The reduced deflections of these three arcs are,

15·3° 22·4°, 29·7°.

"Let us consider them separately; commencing with the first. In the first place, then, 15 degrees according to our calculation, are equal to 15·2; we obtain the value of the decimal 0·3 by multiplying this fraction by the difference 1·1; for we have evidently the proportion

$$1 : 1{\cdot}1 = 0{\cdot}3 : x = 0{\cdot}3$$

The value of the reduced deflection corresponding to the 35th degree, will not, therefore, be 15·3°, but 15·2° + 0·3° = 15·5°. By similar considerations we find 23·5° + 0·6° = 24·1°, instead of 22·4°, and 36·7° instead of 29·7° for the reduced deflections of 40 and 45 degrees.

"It now only remains to calculate the forces belonging to these three deflections, 15·5° 24·1°, and 36·7°, by means of the expression $3{\cdot}333a$; this gives us,

the forces,	51·7,	80·3,	122·3.
for the degrees,	35,	40,	45.

"Comparing these numbers with those of the preceding table, we see that the sensitiveness of our galvanometer diminishes considerably when we use deflections greater than 30 degrees."

When one face of the thermopile is exposed to the action of heat, the needle of the galvanometer, with which the pile is connected, immediately leaves its position of equilibrium and swings considerably beyond the new position in which, after a series of gradually diminishing oscillations, it ultimately comes to rest, if the pile continues exposed to the same source of heat; and when the source of heat is removed, the face of the pile only gradually loses the increased temperature which it had acquired while exposed to its action, so that the return of the galvanometer needle to its first position is likewise gradual. These two circumstances would occasion a very considerable loss of time in making a numerous series of observations with the thermomultiplier, were it necessary each time to allow the needle to become stationary at the point of ultimate deflection; but Melloni observed that the arc through which the needle swings in its first oscillation is always the same for an ultimate deflection of the same amount, and hence, by constructing what he calls a *Table of Impulses*, or table giving the ultimate deflection corresponding to a first swing, or impulse, of any given amount, this loss of time may be avoided. With such a table, it is only necessary to observe the arc described by the needle in its first movement, and then to refer to the table for the ultimate deflection corresponding thereto.

Siemens's *Resistance Thermometer*.—In this instrument the actual indications of temperature are made by an ordinary mercurial thermometer: its peculiarity consists in the fact that it enables the temperatures of spaces to be determined into which a thermometer could not be introduced, or where, if introduced, it could not be observed. Its action depends on the increased resistance which a metallic wire offers to the passage of an electric current when its temperature is raised. (ELECTRICITY, ii. 467.)

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Two perfectly similar coils of insulated wire are enclosed in two hermetically sealed copper cases. One is placed in the space of which the temperature is required, the other in a bath of water; and the temperature of the bath is altered until the electrical resistance of the two coils is exactly equal, an equality which can be readily tested by a differential galvanometer. The temperature of the bath will then clearly be equal to that of the space where the first resistance coil is placed. The connections are made with very thick copper wire, so that their resistance shall have little or no influence upon the result. The wires are coiled on an open copper cylinder of considerable diameter and length, so as to expose a large surface to the air or water in which they are placed. They in consequence take the temperature of the surrounding medium with great rapidity. (*Report on Electrical Instruments in the International Exhibition of* 1862, by Fleeming Jenkin.—Jurors' Reports, Class xiii. p. 93.)

This instrument is obviously adapted for determining the temperature of different depths of the sea, or of borings on land, and for other similar purposes. Its sensibility may be considerably increased by adopting a suggestion of Dr. Esselbach's, and constructing one of the coils, that one which is placed in the bath of water, of a material whose resistance increases more slowly with rise of temperature than that of the substance of which the other coil is made. The temperature of the bath would then have to be varied more than one degree, in order to compensate the alteration of resistance caused by a variation of one degree in the temperature of the medium surrounding the other coil.

Besides the instruments for measuring temperature which are described above and in the article THERMOMETER, already referred to, a great number of others, of various degrees of utility, have been suggested from time to time. But it is believed that the instruments here noticed are those most likely to be found practically useful by the experimental chemist. A large number of the older contrivances for thermometric purposes are very fully described in the treatise on *The Thermometer and Pyrometer*, published by the Society for the Diffusion of Useful Knowledge. (Library of Useful Knowledge, Natural Philosophy, vol. ii. 1832.)

Calorimetry.—The cases in which *quantities* of heat require to be measured are very numerous, and different methods and apparatus are required in nearly every case. In relation to every one of the effects of heat the question arises: How much heat is needed to produce this effect with a given intensity? hence calorimetric measurements have to be made in the study of each of these effects, while the nature of each will determine the manner in which such measurements can best be made. We shall, therefore, consider the different problems into which calorimetry enters, one by one as they occur, and shall now pass at once to the

QUANTITATIVE STUDY OF THE EFFECTS OF HEAT.

The following order will be adopted in this part of the subject:—

1. Changes of Temperature produced by Heat.
2. Changes of Volume produced by Heat.
3. Changes of State of Aggregation produced by Heat.
4. Relations of Heat to Chemical Affinity.
5. Relations of Heat to Electricity.
6. Relations of Heat to Mechanical Energy.

1. *Changes of Temperature produced by Heat.*—**Specific Heat.**—When equal weights of two different substances, say a pound of water and a pound of mercury are placed in two similar vessels, and exposed for the same length of time to the heat of the same lamp, or placed in front of the same fire, at equal distances from it, or otherwise treated so as to have an opportunity of taking up, each exactly as much heat as the other, it is found that, if of equal temperatures at the beginning of the experiment, they have no longer the same temperature at the end of it. The mercury is found to be much hotter than the water. Hence it is proved that a quantity of heat which is sufficient to raise the temperature of a given quantity of mercury through a given number of degrees, is only able to raise the temperature of the same quantity of water through a smaller number of degrees; in other words, more heat is required to raise the temperature of a given quantity of water one degree, than is required to raise the temperature of the same quantity of mercury one degree. Again, if we take two equal weights of water and mercury which have been heated to the same temperature say to 100° C., and place them under such conditions that, in cooling down to the temperature of the atmosphere, each shall give out exactly as much heat in each second as the other, it will be found that the mercury will have cooled down to the temperature of the atmosphere long before the water; hence, when its temperature is lowered by a given number of degrees, water gives out more heat than an equal quantity of mercury does in undergoing a similar alteration of temperature. Extending similar experiments to other substances, we should find that the quantity of heat needed to effect a given

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change of temperature is different for almost every substance. These quantities of heat, expressed relatively to the quantity of heat required to raise the temperature of an equal weight of water from 0° to 1° C., are called the specific heats of the various substances. Thus, for instance, the statement that the specific heat of lead is 0·0314, implies that the quantity of heat which would suffice to raise the temperature of any given quantity of lead from 0° to 1° C., would raise the temperature of an equal quantity of water only from 0° to 0·0314°.

The power of heat, then, to cause changes of temperature depends upon the nature of the substance upon which it acts, just as we shall see in the sequel, that its power to cause changes of volume, or changes of any other kind, varies with the nature of the bodies submitted to its action.

Three principal methods have been employed for measuring the specific heats of different substances. Of these, much the most accurate is that known as the method of mixtures; we shall, therefore, describe it first. It consists in heating a known weight of the substance, whose specific heat is to be determined, to a known temperature, then plunging into a known weight of water, also at a known temperature, and determining the temperature of the mixture which results. In an experiment of this kind, let T be the temperature to which the substance was heated, t the initial temperature of the water, and θ the temperature of the mixture; and let the weight, in grammes, of the substance be W, and the weight of the water, w. Then it is plain that the heat which the substance has given out in cooling from $T°$ to $\theta°$ is the same as that required to heat the water from $t°$ to $\theta°$. Calling the hitherto unknown specific heat of the substance x, we shall have for the former quantity of heat, the expression $W(T-\theta)x$, and for the heat taken up by the water (whose specific heat = 1), $w(\theta - t)$. Hence

$$W(T-\theta)x = w(\theta - t);$$

or

$$x = \frac{w(\theta - t)}{W(T-\theta)}.$$

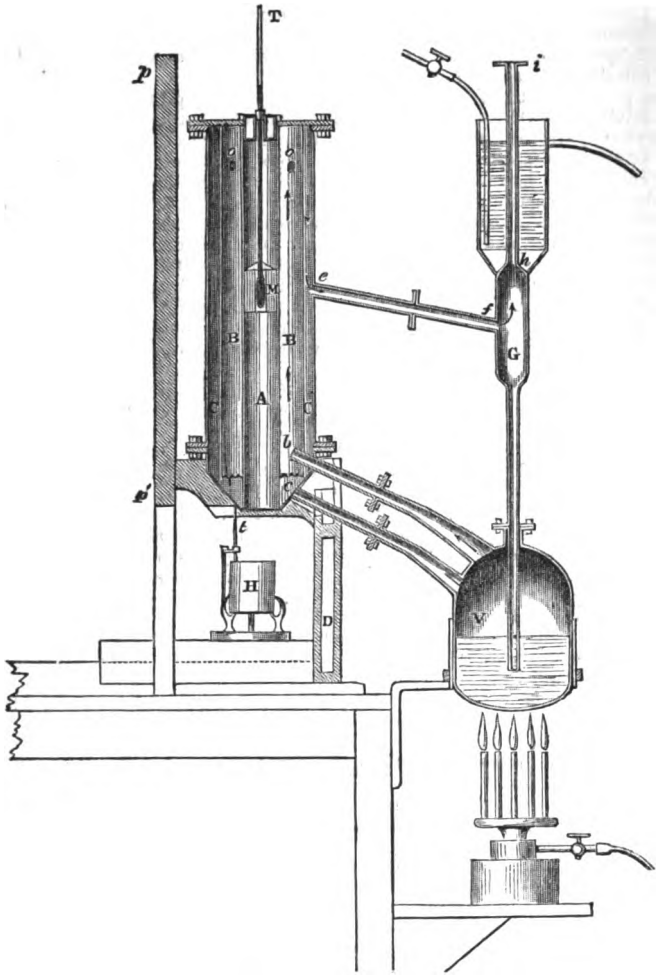
The most accurate determinations of specific heat that have hitherto been published are probably those made by Regnault (Ann. Ch. Phys. lxxiii. 5; *Ibid.* [3] i. 129; ix. 322; xxvi. 261 and 268; xxxviii. 129; xlvi. 257; lxiii. 5), by the method of mixtures. *Fig.* 530 (see p. 26), which is copied from his latest memoir on this subject, shows the disposition of apparatus usually employed by this investigator. The substance to be examined is contained in a basket of fine brass wire, M, suspended in the middle of an upright cylinder, A, of thin metal. This cylinder is surrounded by a larger concentric cylinder, B, and this again by a third cylinder, C. By the ebullition of water in the boiler, V, the annular space between A and B is kept constantly full of steam, which passes thence through the openings, *o o*, near the top of B, into the outer annular space comprised between B and C, and hence by the waste-pipe *ef* to the condenser G, and so back to the boiler. That portion of the steam which is liquefied in the cylinders B and C, returns to the boiler in the form of water by the pipe *c*. The temperature of the substance in M is shown by the thermometer T, the bulb of which occupies a cylindrical space left for the purpose in the middle of the basket of brass wire. The water into which the substance is to be plunged is contained in the calorimeter H, a small vessel of very thin and highly polished brass, supported upon three points, and carried by a foot which slides along a groove, so that, by a rapid and smooth motion, it can be brought directly under A, or removed to the farther side of the sliding screen, *pp'*, so as to be protected from the influence of heat given out by the heating apparatus C. When in its place under A, the calorimeter is protected from heat radiated by the boiler by the double screen D, between the two coatings of which a continual circulation of cold water is kept up. The temperature of the calorimeter is indicated by the thermometer *t*, the bulb of which is long enough to reach from just below the surface of the water to very near the bottom.

At the commencement of an experiment, the calorimeter is drawn back outside the screen *pp'*, and the basket containing the substance to be examined is suspended in the middle of the cylinder A by a silk thread, the cylinder itself being closed at top and bottom by hollow plugs to prevent loss of heat, one of which is shown in its place at the upper part of the figure. Steam from the boiler being allowed to circulate about A, the substance at M is gradually heated to nearly the temperature of boiling water. After, in general, about two hours, the thermometer T becomes stationary; but, for greater certainty that the temperature of the substance is uniform throughout, the heating is continued for at least another hour. The temperature of the water in the calorimeter is then observed by reading the thermometer *t* through a telescope, the temperature of the air being read off at the same time upon another thermometer. The calorimeter is quickly pushed under the heating apparatus; the plug at the bottom of the cylinder A is removed; and by loosening the cork which supports the thermometer T,

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the silk thread from which the basket M hangs is liberated, and this with its contents allowed to fall into the water contained in H. The calorimeter is again drawn back behind the screen PP', and the basket is moved about in the water by an assistant, while the observer watches through the telescope the maximum temperature indicated

Fig. 530.



by the thermometer *t*. This maximum generally occurs one or two minutes after the immersion of the substance. Suppose that, in such an experiment, the following results were obtained:—

Weight of substance	M grm.
„ „ brass wire basket	p grm.
Temperature by thermometer T at moment of immersion . .	$T°$
Temperature by thermometer t at same moment	$t°$
Maximum temperature after immersion by thermometer t . .	$\theta°$
Weight of water in calorimeter, calorimeter and thermometer supposed included	A
Specific heat of brass	c

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Then, calling the required specific heat of the substance C, we should have

$$MC(T-\theta) + pc(T-\theta) = A(\theta - t);$$

or

$$C = \frac{A(\theta - t) - pc(T-\theta)}{M(T-\theta)}$$

In giving the calculation in this very simple form, we are assuming that the constant A includes not merely the actual water in the calorimeter, but also the "water-equivalents" of the brass of which the calorimeter is composed, and of the glass and mercury composing the thermometer t, for these are all heated at the same time as the water, and to the same extent. If the weight of brass in the calorimeter were w, and the weights of glass and mercury in the thermometer t respectively w' and w'', and if, further, the specific heats of brass, glass, and mercury be c, c', and c'', the "water-equivalent" of the calorimeter (or the quantity of water which would require the same quantity of heat to raise its temperature one degree) would be wc, and the "water-equivalent" of the thermometer t would be $w'c' + w''c''$. Hence if a be the weight of actual water in the calorimeter, the calorimetric value of the whole quantity of matter to which the heat of the body under experiment is imparted will be:

$$A = a + wc + w'c' + w''c''.$$

The values of the several terms making up the whole value of A must obviously be determined by preliminary experiments.

An additional correction, the value of which has also to be found by preliminary trials, is required to compensate the heating or cooling effect of the atmosphere upon the calorimeter and its contents during the course of an experiment. But as the difference between the two temperatures t and θ of the calorimeter seldom exceeds 4° or 5°, it is easy, by keeping the temperature of the instrument as much below the atmospheric temperature during the first half of the experiment as it is expected to exceed it in the second half, to render the error introduced by atmospheric heating or cooling, very small indeed: in Regnault's experiments, it amounted to only three or four hundredths of a degree, but was nevertheless carefully allowed for.

By means of the apparatus above described, the substance under examination can never be heated quite to the boiling point of the liquid in the boiler V, so that when this is water, the temperature of the substance never rises above 97° or 98°; but any other temperature that may be desired can easily be attained by introducing into the boiler, in place of water, a liquid which boils at nearly the required temperature, and then raising or lowering its temperature of ebullition as much as may be needed, by connecting the tube h i with a large reservoir of compressed or rarefied air.

In determining the specific heat of substances (such as phosphorus, for example) which could not be heated without causing them to melt or else to undergo other alterations which would interfere with the accuracy of the results, Regnault adopted an inverse process, and cooled them to a temperature considerably below that of the water in the calorimeter, and thus observed the diminution in the temperature of the latter which resulted from immersing the cooled substances in it. The apparatus employed for producing and maintaining constant a low temperature, resembles to some extent the heating apparatus already described and figured. It consists of a central tube, in the middle of which is suspended the substance to be cooled, surrounded by two larger concentric cylinders. The space between the central tube and the next is partially filled with ether or some other volatile liquid, and the space between this tube and the outside one is filled with air. By causing a rapid current of air to traverse the ether, its temperature is gradually lowered, and with an external temperature of 20° C. any temperature not lower than −12° can be maintained constant by properly regulating the flow of air; the lowest temperature that can be obtained under similar circumstances, by employing sulphide of carbon instead of ether is − 8°. By the use of liquid ammonia, any temperature between −40° and −80° C. can be obtained.

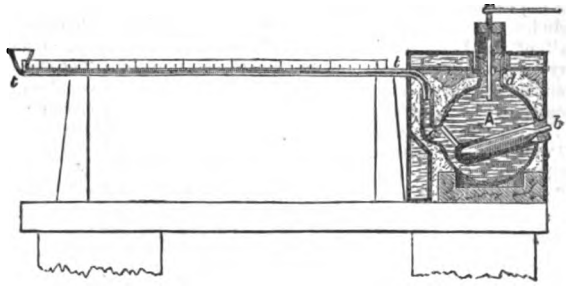
In order to apply the above method to determinations of the specific heat of liquids, they must be enclosed in tubes of very thin glass, nearly filled and hermetically closed. These tubes are suspended, like the basket M, in the centre of the tube A, and afterwards let down into the calorimeter. In calculating the result, allowance must of course be made for the heat imparted to the calorimeter by the tube.

Another apparatus which serves for the determination of specific heats is represented in *fig.* 531. This apparatus, devised by Favre and Silbermann (Ann. Ch. Phys. [3] xxxvi. 33), consists of a glass globe, A, of about 1 litre capacity, in which are three openings. The first, *b*, admits a thin iron or platinum tube, closed at the lower end, about 1 inch (2½ to 3 centimetres) wide and 4 inches (10 or 11 centimetres) long, cemented at the top into the opening of the glass, and kept in its

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place below by a piece of glass rod, one end of which is cemented against the upper side of the tube and the other end against the side of the glass globe. Within this tube, which is called the *muffle*, is placed another tube of very thin glass which serves to contain the substances under experiment. This is held in its place by a

Fig. 531.



cork which surrounds its neck and fits tightly in the mouth of the muffle; it is surrounded by about 100 grms. of mercury, intended to facilitate interchange of heat between it and the muffle.

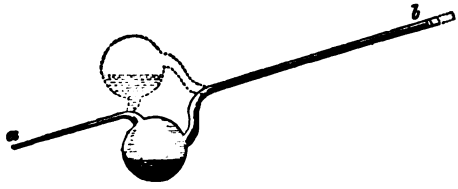
The second opening, *c*, carries a horizontal capillary tube, *tt*, about 500 millimetres long, divided into millimetres, and terminated at the farther end by a small funnel. This tube, which should be perfectly cylindrical, is cemented to the glass globe by marine glue, so that, when needful, it can be easily removed and cleaned.

The third opening carries a steel piston, *d*, which, by means of a screw, can be raised or lowered so as to increase or diminish somewhat the capacity of the globe.

The globe itself is supported upon a thick ring of cork and enclosed in a box lined with wadding or swan's-down, and surrounded by a double casing filled with water. It is filled with mercury, with the precautions necessary to exclude any trace of air, and the extremity of the column of mercury is adjusted by moving the steel piston, *d*, up or down, so as to be exactly at the zero point of the divisions of the tube.

In using the instrument, the substance whose specific heat is to be determined, is introduced at a known temperature into the muffle, or into the glass tube inside it. The substance then parts with its heat to the mercury contained in the globe of the calorimeter, causing it to expand, and the expansion read off on the tube *tt* is a measure of the quantity of heat thus imparted to the mercury. In order, however, to compare the indications of this instrument with those of the water-calorimeter, it is needful to know the number of divisions of the tube *tt* which correspond to the effect of a unit of heat, or gramme-degree. For this purpose Favre and Silbermann graduated their instrument as follows:—A few scraps of platinum wire, and 4 or 5 grammes of distilled water, are placed in a pipette of the form shown in *fig.* 532. The pipette is heated over a spirit-lamp until the water boils, the flame being occasionally passed along the point *a*, so as to heat it sufficiently to prevent the condensation of steam, and the drop of water is removed from the end by a piece of filter-paper, so that the steam may have free issue into the air at the moment of beginning the experiment.

Fig. 532.



The lamp is then removed for an instant; the ebullition ceases, and at the same moment the point of the pipette is rapidly introduced to the bottom of the tube contained in the muffle, the pipette being simultaneously turned round through 180° about the axis *ab*. The lamp is then again brought near the pipette, and the cork which closes the upper end is removed, so that no steam may follow the water into the muffle. As soon as the mercury-column in *tt* has reached the extreme point, the temperature of the water is taken by a small and sensitive thermometer; and the experiment is completed by weighing the glass tube with the water contained in it.

If the weight of water be P, and the number of degrees through which its temperature falls after being introduced into the tube of the muffle be T, the number of units of heat imparted to the calorimeter will be PT. If this quantity of heat causes the mercury to advance through N divisions of the tube *tt*, the amount of

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expansion, C, expressed in the same divisions, corresponding to one unit of heat will be

$$C = \frac{N}{PT}.$$

Favre and Silbermann found that, in the instrument employed by them, one unit of heat caused the mercury to advance in *tt* by 0·3 millimetre.

In determining the specific heats of liquid substances by means of this apparatus, they are introduced into the tube of the muffle by means of the pipette *ab*, in the manner already described in the case of water, the weight employed being determined after the experiment.

Another method of ascertaining the specific heats of various substances consists in determining the quantity of ice which can be melted by the heat given off by a known weight of each while cooling through the same number of degrees. A known weight of the substance to be operated upon is heated to a determinate temperature, as 100°, and then placed in a cavity scooped out of a block of melting ice and covered by a second slab of ice. The temperature of the substance is thus brought down to that of melting ice, and a quantity of ice is melted—that is, a quantity of water is formed—proportionate to the quantity of heat which the substance gives out in cooling to this temperature.

This method, however, though very simple both in principle and in execution, cannot be made to give very accurate results; for there is great difficulty in determining with exactness the quantity of water formed, and a small error committed here will introduce a large error into the estimate of the quantity of heat given out by the body in cooling, since as will be seen hereafter, the quantity of heat needed to convert one part of ice into water would be sufficient to raise the temperature of 79¼ parts of water one degree.

A third method, called the method of cooling, was employed by Dulong and Petit. It consists in determining the length of time which the different substances to be examined require in order to cool in a vacuum from one known temperature to another, each being placed, as nearly as possible, under identical circumstances.

In order to realise the necessary conditions for determinations of this kind, the substances to be examined are all reduced to an impalpable powder, and filled successively into the same cylindrical silver vessel, gilded and highly polished externally, in the axis of which is the bulb of the thermometer by which the progress of the cooling is to be shown. The silver vessel, supported by the stem of the thermometer, is suspended in the middle of a large brass receiver, coated internally with lamp-black, from which the air can be completely removed. This is immersed in water at 40° C., and when the thermometer inside the apparatus marks 35°, it is transferred to melting ice. The thermometer is now watched through a telescope, and the instants at which it marks 20°, 15°, 10°, and 5°, are noted. If all other circumstances were the same, the time during which each substance underwent the same fall of temperature, would be a measure of the amount of heat given out in undergoing this change—that is, of the specific heat of the substance; but Regnault, who submitted this method to very careful examination (Ann. Ch. Phys. [3] ix. 327), found that it was impossible to obtain results of any value by its application in the case of solid bodies: with liquids, for which the same sources of error do not occur as for solids, it is capable of giving much more exact results.

The difficulties attendant on the exact determination of the specific heats of gases and vapours are very much greater than in the case of solids and liquids. An extensive series of experiments on this subject has been made by Regnault (Mém. de l' Acad. des Sciences, xxvi. 41) with elaborate care, the principle of his method being to observe the alteration of the temperature of water, surrounding a spiral tube, caused by the passage through the tube of a known quantity of gas which enters and issues from it at known temperatures. A description of the apparatus employed in these researches and of the methods of experimenting would occupy too much space to admit of its being given here; we must therefore refer for details to the paper already quoted. (A figure of the apparatus and a tolerably full account of the method of experimenting are also given in Daguin's *Traité de Physique*, 2nd edit. ii. 275–280.) The principal results obtained are enumerated below (p. 35).

In the following Table are given the specific heats of a considerable number of the elementary bodies, according to the results obtained by Regnault by the method of mixtures. When the specific heat of the same element has been determined by him several times, the most recent result is given in the Table. The third column gives the temperatures between which the specific heats given in the second column were observed; the numbers contained in the fourth and fifth columns will be referred to presently. The specific heats of the gaseous elements are not included in this table, but will be found in a subsequent one, together with the specific heats of some other gases (see p. 35).

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Table of Specific Heats of the Elements.

Name.	Specific heat.	Temperature.	Atomic weight.	Product of sp. ht. × at. wt.
Lithium	0·94080	100° to 27°	7	6·59
Sodium	·29340	6 „ −32	23	6·75
Magnesium	·24990	98 „ 23	24	6·00
Aluminium (sp. heat corrected for 2 p. c. iron impurity)	·21430	97 „ 14	27·5	5·89
Phosphorus liquid	·21200	100 „ 50	31	6·57
Phosphorus solid	·18870	30 „ −10	31	5·85
Phosphorus „	·17400	10 „ −78	31	5·39
Phosphorus amorphous	·17000	98 „ 15	31	5·27
Sulphur (recently melted)	·20259	98 „ 14	32	6·48
Sulphur (native)	·17760	99 „ 14	32	5·68
Potassium	·16956	0 „ −78	39	6·61
Manganese (containing a trace of silicon)	·12170	97 „ 14	55	6·69
Iron	·11380	98 „ 17	56	6·37
Nickel specimen I. (1840)	·10863	99 „ 13	58·7	6·37
Nickel „ II. (1859)	·10752	97 „ 17	58·7	6·31
Nickel „ III. (1859)	·11080	97 „ 12	58·7	6·50
Cobalt specimen I. (1840)	·10696	99 „ 12	58·7	6·28
Cobalt „ II. (1859)	·10620	98 „ 10	58·7	6·23
Cobalt „ III. (1859)	·10730	97 „ 8	58·7	6·30
Copper	·09515	98 „ 15	63·5	6·04
Zinc	·09555	99 „ 14	65	6·21
Arsenic	·08140	98 „ 13	75	6·11
Selenium metallic	·07616	97 „ 21	79	6·02
Selenium metallic	·07446	7 „ −18	79	5·88
Selenium vitreous	·10310	82 „ 19	79	8·15
Selenium vitreous	·07468	8 „ −24	79	5·90
Bromine solid	·08432	−20 „ −78	80	6·75
Bromine liquid	·11294	58 „ 13		
Bromine liquid	·11094	48 „ 10		
Bromine liquid	·10513	10 „ − 6		
Molybdenum (impure)	·07218	98 „ 12	96	6·93
Rhodium specimen I.	·05527	98 „ 20	104·4	5·77
Rhodium „ II.	·05803	97 „ 11	104·4	6·07
Palladium	·05928	98 „ 14	106	6·28
Silver	·05701	99 „ 13	108	6·16
Cadmium (containing 1 per cent. impurity)	·05669	98 „ 16	112	6·35
Tin	·05623	99 „ 12	118	6·63
Uranium (impure)	·06190	98 „ 10	120	7·43
Antimony	·05077	97 „ 12	122	6·19
Iodine	·05412	98 „ 9	127	6·87
Tellurium	·04737	98 „ 18	128	6·06
Tungsten	·03342	98 „ 12	184	6·15
Gold	·03244	98 „ 12	196	6·36
Iridium	·03259	99 „ 17	198	6·45
Platinum	·03243	99 „ 12	198	6·42
Osmium	·03113	98 „ 19	199·2	6·20
Mercury solid	·03192	−40 „ −78	200	6·38
Mercury liquid	·03332	98 „ 12	200	6·66
Thallium according to Lamy	·03250		204	6·63
Thallium „ Regnault	·03355	100 „ 17	204	6·84
Lead	·03140	98 „ 15	207	6·50
Lead	·03065	10 „ −78	207	6·35
Bismuth	·03084	98 „ 13	210	6·48
Boron graphitic	·23520	99 „ 17	11	2·59
Boron crystallised	·25000	100 „ 11	11	2·75
Carbon wood charcoal	·24150	98 „ 8	12	2·90
Carbon graphite	·20083	98 „ 12	12	2·41
Carbon diamond	·14687	98 „ 9	12	1·76
Silicon crystallised	·17740	99 „ 12	28	4·97
Silicon fused	·17500	100 „ 22	28	4·90

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The following short table gives the specific heats of a few substances which require to be taken into account in calculating the results of the experiments from which the numbers in the foregoing and subsequent tables are deduced:—

Name of Substance.	Specific heat.	Temperatures between which the specific heat was observed.
Brass	0·09391	98° and 12°
Glass	0·19768	99 „ 14
Oil of turpentine	0·42593	98 „ 15
Water	1·00800	98 „ 13

Numerous determinations have been made by Regnault of the specific heats of inorganic compounds. A selection from his results, sufficient to show their general nature, is given in the next table. The temperatures between which the determinations were made are not given in the table, but were in all cases a temperature approaching 100° C., and a temperature near that of the atmosphere. In the case of substances which are soluble in water, or capable of being chemically acted on by it in any way, the calorimeter was filled with oil of turpentine. The different substances enumerated in the table are arranged in groups according to their chemical composition.

Table of Specific Heats of Inorganic Compounds.

Name of Substance.	Formula.	Specific heat.	Molecular weight.	Product of sp. heat × mol. weight.
A.—Diatomic Molecules.				
1. *Oxides*	MO			
Protoxide of lead (fused)	PbO	0·05089	223	11·35
Oxide of mercury	HgO	·05179	216	11·19
Protoxide of manganese	MnO	·15701	71	11·15
Oxide of copper	CuO	·14201	79·5	11·19
Oxide of nickel (calcined)	NiO	·15885	74·7	11·87
Magnesia	MgO	·24394	40	9·76
Oxide of zinc	ZnO	·12480	81	10·11
2. *Sulphides*	MS			
Protosulphide of iron	FeS	·13570	88	11·94
Sulphide of nickel	NiS	·12813	90·7	11·62
„ cobalt	CoS	·12512	90·7	11·36
„ zinc	ZnS	·12303	97	11·93
„ lead	PbS	·05086	239	12·15
„ mercury	HgS	·05117	232	11·87
Stannous sulphide	SnS	·08375	150	12·56
3. *Chlorides*	MCl			
Chloride of lithium	LiCl	·28213	42·5	11·99
„ sodium	NaCl	·21401	58·5	12·52
„ potassium	KCl	·17295	74·5	12·88
„ silver	AgCl	·09109	143·5	13·07
Mercurous chloride	HgCl	·05205	236·5	12·26
Cuprous „	CuCl	·13827	99·0	13·69
4. *Bromides*	MBr			
Bromide of potassium	KBr	·11322	119	13·47
„ silver	AgBr	·07391	188	13·90
„ sodium	NaBr	·13842	103	14·26
5. *Iodides*	MI			
Iodide of potassium	KI	·08191	166	13·60
Iodide of sodium	NaI	·08684	150	13·03
Mercurous iodide	HgI	·03949	327	12·91
Iodide of silver	AgI	·06159	235	14·47
Cuprous iodide	CuI	·06869	190·5	13·09
B.—Triatomic Molecules.				
1. *Oxides*	MO^2			
Stannic oxide	SnO^2	·09326	150	13·99

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Table of Specific Heats of Inorganic Compounds—continued.

Name of Substance.	Formula.	Specific heat.	Molecular weight.	Product of sp. heat × mol. weight.
TRIATOMIC MOLECULES *continued*—				
Titanic anhydride (artificial)	TiO^2	0·17164	82	14·07
„ „ (rutile)	TiO^2	·17032	82	13·97
Silicic anhydride	SiO^2	·19132	60	11·48
Intermediate oxide of antimony	SbO^2	·09535	154	14·70
2. *Sulphides*	MS^2			
Iron pyrites	FeS^2	·13009	120	15·61
Stannic sulphide	SnS^2	·11932	182	21·72
Disulphide of molybdenum	MoS^2	·12334	160	19·73
3. *Chlorides*				
Chloride of barium	$BaCl^2$	·08957	208	18·63
„ strontium	$SrCl^2$	·11990	158·6	19·02
„ calcium	$CaCl^2$	·16420	111	18·23
„ magnesium	$MgCl^2$	·19460	95	18·49
„ mercury	$HgCl^2$	·06889	271	18·67
„ zinc	$ZnCl^2$	·13618	136	18·52
„ lead	$PbCl^2$	·06641	278	18·46
„ manganese	$MnCl^2$	·14255	126	17·96
Stannous chloride	$SnCl^2$	·10161	189	19·20
4. *Iodides*	MI^2			
Iodide of lead	PbI^2	·04267	461	19·65
„ mercury	HgI^2	·04197	454	19·07
C.—TETRATOMIC MOLECULES.				
1. *Oxides*	MO^3			
Tungstic anhydride	WoO^3	·07983	232	18·52
Molybdic anhydride	MoO^3	·13240	144	19·07
2. *Chlorides*	MCl^3			
Chloride of arsenic	$AsCl^3$	·17604	181·5	31·95
Trichloride of phosphorus	PCl^3	·20922	137·5	28·77
D.—PENTATOMIC MOLECULES.				
1. *Simple oxides*	M^2O^3			
Alumina {corundum	Al^2O^3	·19762	103	20·35
Alumina {sapphire	Al^2O^3	·21732	103	22·38
Specular iron	Fe^2O^3	·16695	160	26·71
Arsenious anhydride	As^2O^3	·12786	198	23·01
Oxide of chromium	Cr^2O^3	·17960	153	27·47
„ bismuth	Bi^2O^3	·06053	468	28·33
„ antimony	Sb^2O^3	·09009	292	26·31
2. *Mixed oxides*	MNO^3			
a. Nitrates.				
Nitrate of potassium	NKO^3	·23875	101	24·11
„ sodium	$NNaO^3$	·27821	85	23·65
„ silver	$NAgO^3$	·14352	170	24·39
b. Carbonates.				
Carbonate of calcium {Iceland spar	$CCaO^3$	·20858	100	20·86
Carbonate of calcium {Arragonite	$CCaO^3$	·20850	100	20·85
Carbonate of calcium {saccharoïd marble	$CCaO^3$	·21585	100	21·58
Carbonate of calcium {„ „ grey	$CCaO^3$	·20989	100	20·99
Carbonate of calcium {white chalk	$CCaO^3$	·21485	100	21·48
Carbonate of barium	$CBaO^3$	·11038	197	21·74
„ strontium	$CSrO^3$	·14483	147·6	21·38
„ iron	$CFeO^3$	·19345	116	22·44
3. *Sulphides*	M^2S^3			
Sulphide of antimony	Sb^2S^3	·08403	340	28·57
„ bismuth	Bi^2S^3	·06002	516	30·97
4. *Chlorides*	MCl^4			
Stannic chloride	$SnCl^4$	·14759	260	38·37
Chloride of titanium	$TiCl^4$	·19145	192	36·76

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Table of Specific Heats of Inorganic Compounds—continued.

Name of Substance.	Formula.	Specific heat.	Molecular weight.	Product of sp. heat × mol. weight.
E.—Hexatomic Molecules.				
1. *Sulphates*	SMO^4			
Sulphate of barium . . .	$SBaO^4$	0·11285	233	26·28
„ strontium . . .	$SSrO^4$	·14279	183·6	26·36
„ calcium . . .	$SCaO^4$	·19656	136	26·73
„ lead . . .	$SPbO^4$	·08723	303	26·43
„ magnesium . .	$SMgO^4$	·22159	120	26·59
2. *Carbonates*	CM^2O^3			
Carbonate of potassium . .	CK^2O^3	·21623	138	29·84
„ sodium . .	CNa^2O^3	·27275	106	28·91
F.—Heptatomic Molecules.				
1. *Sulphates*	SM^2O^4			
Sulphate of potassium . .	SK^2O^4	·19010	174	33·08
„ sodium . . .	SNa^2O^4	·23115	142	32·82

For a numerous series of determinations of the specific heats of the isomorphous sulphates of the magnesian group, see Pape (Pogg. Ann. cxx. 337).

With regard to alloys of two or more metals, Regnault found that, at temperatures considerably removed from their melting points, their specific heats are the means of the specific heats of their components. In the following table, the values given in the column headed "Calculated Specific Heats" are obtained by multiplying the specific heat of each constituent into the percentage amount of it contained in the alloy, and dividing the sum of all these products for each alloy by 100; these values, therefore, would exactly represent the specific heats of the respective alloys if the above rule were rigorously true; the correspondence between them and the results of direct observation is sufficient to show that the rule is, at least, a close approximation to the truth.

Specific Heat of Alloys.

Composition of Alloy.	Observed specific heat.	Calculated specific heat.
1 at. lead + 1 at. tin	0·04073	0·04039
1 „ + 2 at. tin	·04506	·04461
1 „ + 1 at. antimony	·03880	·03883
1 at. bismuth + 1 at. tin	·04000	·03987
1 „ + 2 at. tin	·04504	·04415
1 „ + 2 at. tin + 1 at. antimony .	·04621	·04564
1 „ + 2 at. tin + 1 at. antimony + 2 at. zinc . . .	·05657	·05479

In the case of alloys which, at the temperature of observation, were approaching their melting points, the observed specific heat was always considerably higher than that calculated as above.

The specific heats of a few liquids are included in the tables already given (pp. 30 and 32): we append here the results obtained by Person (Ann. Ch. Phys. [3] xxi. 333; xxiv. 136), H. Kopp (Pogg. Ann. lxxv. 98) and Favre and Silbermann (Comptes rend. xxiii. 524; also Ann. Ch. Phys. [3] xxxvii. 464–470) for some additional liquids, simple and compound. Favre and Silbermann's experiments were made by cooling the liquids in the mercurial calorimeter (p. 28), from their respective boiling points to temperatures nearly equal to that of the surrounding atmosphere.

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Specific Heats of Liquids.

Liquids.	Temperature.	Specific heat.	Observers.
Lead	350° to 450°	0·0402	Person
Sulphur	120 „ 150	·234	„
Bismuth	280 „ 380	·0363	„
Tin	250 „ 350	·0637	„
Crystallised chloride of calcium	33 „ 80	·555	„
Nitrate of sodium	320 „ 430	·413	„
Nitrate of potassium	350 „ 435	·3319	„
Mercury	44 „ 24	·0332	Kopp
Iodine	. . .	·10822	F. S.
Bromine	45 „ 11	·107	Andrews
Sulphuric acid	46 „ 21	·343	Kopp
Wood-spirit	43 „ 23	·645	„
		·6713	F. S.
Alcohol	43 „ 23	·615	Kopp
		·6438	F. S.
Fusel-oil	44 „ 26	·564	Kopp
		·5873	F. S.
Ethal	. . .	·5059	„
Ether	. . .	·50342	„
Formic acid	45 „ 24	·536	Kopp
Acetic acid	45 „ 24	·509	„
Butyric acid	45 „ 21	·503	„
Formate of ethyl	39 „ 20	·513	„
Acetate of methyl	41 „ 21	·507	„
Acetate of ethyl	45 „ 21	·496	„
		·48344	F. S.
Butyrate of methyl	45 „ 21	·487	Kopp
		·49176	F. S.
Valerate of methyl	45 „ 21	·491	Kopp
Acetone	41 „ 20	·530	„
Benzene	46 „ 19	·450	„
Oil of mustard	48 „ 28	·482	„
Oil of turpentine	. . .	·46727	F. S.

The specific heat of water at different temperatures has been determined by Regnault (Mém. Acad. Sciences, xxi. 729) from whose experiments it appears that the quantity of heat expressed in *heat-units* which one gramme of water loses in cooling down from $t°$ to 0° C. is given by the formula,—

$$Q = t + 0{\cdot}00002\,t^2 + 0{\cdot}0000003\,t^3;$$

and the specific heat C at the temperature $t°$, that is to say, the quantity of heat required to raise one gramme of water from $t°$ to $(t + 1)°$, by the formula,—

$$C = 1 + 0{\cdot}00004\,t + 0{\cdot}0000009\,t^2.$$

From this formula, the following numbers are obtained:

Specific Heat of Water.

t.	Q.	C.	t.	Q.	C.
0°	0·000	1·0000	150°	151·462	1·0262
50	50·087	1·0042	200	203·200	1·0440
100	100·500	1·0130	230	234·708	1·0568

The specific heat of ice is considerably less than that of liquid water. According to Regnault's experiments, it is 0·474 between −78° and 0° C., and 0·504 between −20° and 0°, according to the experiments of Person and of Desains.

It results from Regnault's determinations of the specific heats of gases and vapours, made in the manner already mentioned (p. 29), that the specific heat of a given *weight* of a gas which obeys Boyle's law (Gases, ii. 820) does not alter with variations either of temperature or of pressure. This was found to be true of atmospheric air

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between the temperatures of − 20° and + 225°, and at pressures varying from 1 to 12 atmospheres. Consequently the specific heat of a given *volume* of air, or other non-condensable gas, varies directly as its density. In gases which do not follow Boyle's law, this regularity does not exist: thus the specific heat of carbonic anhydride is found to increase perceptibly as its temperature rises, being 0·18427 between −30° and 10°, and 0·20246 between 10° and 100°, and 0·21692 between 10° and 210°, as compared with that of an equal weight of water.

The following table gives the specific heats of the various gases and vapours examined by Regnault, compared, first, with an equal weight of water taken as unity, secondly, with that of an equal volume of air referred as before to its own weight of water as unity. The latter series of numbers is obtained by multiplying the numbers expressing the specific heats of equal weights of the various gases or vapours, by their respective densities referred to that of air as 1.

Table of Specific Heats of Gases and Vapours. (Regnault.)

Name.		Specific heats.	
		Equal weights.	Equal volumes.
Simple or mixed gases	Air	0·2374	0·2374
	Oxygen	·2175	·2405
	Nitrogen	·2438	·2368
	Hydrogen	3·4090	·2359
	Chlorine	·1210	·2965
	Bromine	·0555	·3040
Compound gases	Nitrous oxide	·2262	·3447
	Nitric oxide	·2317	·2406
	Carbonic oxide	·2450	·2370
	Carbonic anhydride	·2163	·3307
	Sulphurous anhydride	·1544	·3414
	Hydrochloric acid	·1852	·2333
	Sulphydric acid	·2432	·2857
	Ammonia	·5084	·2996
	Marsh-gas	·5929	·3277
	Olefiant gas	·4040	·3907
Vapours	Water	·4805	·2989
	Sulphide of carbon	·1569	·4122
	Alcohol	·4534	·7171
	Methylic alcohol	·4580	·5063
	Ether	·4797	1·2267
	Chloride of ethyl	·2738	·6096
	Bromide of ethyl	·1896	·7026
	Sulphide of ethyl	·4008	1·2466
	Cyanide of ethyl	·4262	·8105
	Chloroform	·1567	·6461
	Chloride of ethylene	·2293	·7836
	Acetate of ethyl	·4008	1·2184
	Acetone	·4125	·8264
	Benzene	·3754	1·0114
	Oil of turpentine	·5061	2·3776
	Trichloride of phosphorus	·1347	·6395
	Chloride of arsenic	·1122	·7034
	Chloride of silicon	·1322	·7778
	Stannic chloride	·0939	·8416
	Chloride of titanium	·1290	·8564

Comparing these values with those given for some of the same substances in previous tables, it appears that the specific heat of the same body is commonly greater in the liquid than in the solid state, and always less in the gaseous than in the liquid state.

On examining the numbers above given for the specific heats of different bodies, it will be seen that the specific heat of a substance is not altogether an absolute and unchangeable property: on the contrary, it will be evident that this property, in one and the same substance, is capable of considerable variation, depending (*a*) on the

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physical structure of the substance, (*b*) on its temperature, (*c*) on its state of aggreg tion. In illustration of this remark, it will be sufficient to refer to the specific heats carbon, silicon, selenium, sulphur, phosphorus, alumina, and carbonate of calcium, given in the foregoing tables, in evidence of the influence of differences of physic condition; to the specific heats of lead, phosphorus, water, and ice, in evidence of t effect of differences of temperature; and to those of bromine, mercury, tin, lead, bismut water, &c., in the solid and liquid states, in evidence of the effect of the state of aggr gation.

In reference to the connection between specific heat and temperature, it may remarked that this property varies to a greater extent, for a given interval of temp rature, near the temperatures at which changes in the state of aggregation occu than at a distance from those temperatures. Thus, the specific heat of lead, an easi fusible metal, is considerably greater between 10° and 100° C. (=0·0314) than it between 10° and −78° C. (=0·0306); and that of phosphorus, a still more fusib substance, shows even a greater difference when compared between 10° and 3 (specific heat = 0·1887) and between −71° and 10° C. (specific heat = 0·1740 while the specific heat of platinum, one of the most infusible of all the metals, vari to a scarcely perceptible extent at temperatures below 100° C., and only slowly temperatures considerably higher. The mean specific heat of this metal between 0° and the temperatures enumerated below, was in fact found by Pouillet to be repr sented by the numbers contained in the second line of the following table.

Specific Heat of Platinum.

Interval of temperature	0° and 100°	0° and 300°	0° and 500°	0° and 700°	0° and 1000°	0° and 1200
Mean specific heat .	0·0335	0·03434	0·03518	0·03602	0·03728	0·03806

The specific heat of solid bodies therefore increases with rise of temperature, up their melting points, and at this temperature there is generally a further sudd increase of specific heat of a considerable amount.

It may be further noticed that in the table of the specific heats of the elemen (p. 30), the elements are arranged nearly in the order of their specific heats, beginni with lithium (specific heat = 0·941) and ending (if we disregard for the present t three elements carbon, boron, and silicon, which are placed together after the rest) wi bismuth (specific heat 0·031); and that this order is also exactly the inverse order of th atomic weights, as given in the fourth column, the atomic weight of lithium (= being less than that of any other element included in the table, and that of bismu (= 210) being greater than that of any other element. In fact, not only do thc elements whose atomic weight is lowest possess, as a rule, the greatest specific he and *vice versâ*, but the specific heats of the elements (in the solid state) are, with comparatively narrow limits, inversely proportional to their atomic weights, wh these are taken as having the values given in the fourth column of the table; so th the product of the specific heats of the elements into their atomic weights is nearly constant quantity; as shown by the numbers in the fifth column of the table. Th numbers may be taken to represent the *atomic heats* of the elements, or the relati quantities of heat which must be imparted to, or removed from, atomic proportions the several elements, in order to cause in them equal alterations of temperature. T table shows that the atomic heats of the elements are not represented by an absolut constant quantity: but when it is considered that the two factors (atomic weight a specific heat) of which they are made up, vary in the proportion of 1 : 30, it cannot denied that they are comprised between comparatively very narrow limits: for (taki those determinations only which refer to comparable conditions of the several elemen and which there is reason to believe were made upon nearly pure substances) we fi that they are nearly all included between 5·9 (aluminium, rhodium) and 6·9 (iodin the greater number not differing much from 6·5. (The high atomic heat of uraniu 7·4, is doubtless to be explained by the impurity of the metal operated upon.) T general accordance is amply sufficient to indicate the existence of a general la although the individual results show the effect of some one or more disturbing caus And even if it be admitted that the true atomic heats of the elements under conside tion are really identical, under comparable circumstances, there are several reasons w the experimental atomic heats, deduced like those in the foregoing table, cannot expected to exhibit the same identity. The most important of these reasons are: t unavoidable experimental errors attaching to the determination of the specific heat the imperfect purity of some of the elements examined; the circumstance that, althou most of the determinations were made at nearly the same absolute temperatures—name between a temperature near 100° and that of the atmosphere—the different elemei

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are not, in regard to their specific heats, under comparable circumstances at these temperatures, some being much nearer to their melting point than others, and therefore having in general relatively higher specific heats (see p. 36); lastly, in a few cases, the uncertainty of the experimental data used in fixing the atomic weights.

The relation of approximate equality among the atomic heats of the elements exists, however, only when their atomic weights are allowed to have the values given in the table: these values are in very many cases the double of those given in the table of atomic weights, vol. i. pp. 464, 465, and employed in the first edition of this work. If the latter scale of atomic weights be adopted, the elements would have to be divided into two classes: those whose atomic heat is approximately 6·5, and those whose atomic heat is approximately 3·2. The fact that, by doubling the atomic weights of the latter class of elements, their atomic heats would be brought into harmony with those of the former class, is in itself a strong argument in favour of such a change; and by reference to the articles ATOMIC WEIGHTS (i. 468–473) and CLASSIFICATION (i. 1008, 1009, foot-note) and the article ATOMICITY in the SUPPLEMENT, it will be seen that it is supported by many other considerations, both chemical and physical. In any case it is certain that the numbers in the column headed "Atomic Weights," in the table on p. 30, represent quantities of the various elements which are calorimetrically comparable; and it is therefore best to assume these numbers as really representing those weights of the elements which, in relation to the phenomena of heat, possess the properties of atoms. Whether the chemical atoms of the elements are always identical with the calorimetric atoms, is a question that is perhaps still open to discussion.

It is very important, however, not to overlook the fact that the atomic heats of boron, carbon, and silicon form unquestionable exceptions to the general rule, and cannot be brought into harmony with it, by the adoption of any atomic weights to which the present state of chemical knowledge lends any serious support.

The examples which have been given (pp. 31–33) of the specific heats of compound bodies, show that, within certain classes of allied compounds, the same kind of relation subsists between their specific heats and molecular weights, as has been pointed out between the specific heats and atomic weights of the elements. Consequently, the molecular heats of the substances comprised in each such class, or the products of their specific heats into their molecular weights (see the last column of the table), are approximately equal. In calculating these molecular heats, the atomic weights of the elements are taken as having the values which may be deduced from their specific heats; those values, namely, which are given in the previous table. Adopting these atomic weights, it will be seen that, as a rule, the molecular heat of solid compound bodies increases with the number of atoms contained in their molecule. For instance, the molecular heat of the oxides MO enumerated in the table averages about 11; that of the oxides MO^2, about 14; that of the oxides MO^3, about 19; that of the oxides M^2O^3, about 25·5.

An extensive series of determinations of the specific heats of solid bodies has been made by H. Kopp, but the individual results have not yet been published (1864); we shall, therefore, instead of discussing any further the relations between specific heat and chemical composition which might be deduced from Regnault's experiments already given, reproduce here the substance of the remarks which Kopp (Ann. Ch. Pharm. cxxvi. 362), with his own results before him, makes upon this subject.

This new investigation has brought to light a considerable number of additional examples of solid compounds which, having an analogous atomic constitution, possess also approximately the same molecular heat. Among these, particular interest attaches to the case in which an analogy of constitution is apparent only when the atomic weights of the elements are admitted to have the values assigned to them in the foregoing tables, and where the formulæ previously adopted and the old atomic weights of the elements would never have caused any such relations between specific heat and molecular weight to be suspected. Just as the molecular heats of carbonates and silicates, $M''CO^3$ and $M''SiO^3$, and of nitrates and chlorates, MNO^3 and $MClO^3$, are approximately equal, so also are the molecular heats of the permanganates and perchlorates, $MMnO^4$ and $MClO^4$, and of the sulphates and chromates, $M''SO^4$ and $M''CrO^4$. The new investigation, however, also furnishes some additional examples to the previously known exceptions to the general rule, and thus supplies further evidence of the fact that it is possible for bodies of analogous constitution to differ considerably in their molecular heats.

The molecular heat of a compound appears to be governed only by its empirical, and not by its rational constitution. Analogous compounds, in one of which a complex group occupies the place of an elementary atom, were found, even when isomorphous,

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to have unequal molecular heats; thus the molecular heats of the ammonium-compounds are considerably greater than those of the corresponding potassium-compounds, and those of the cyanogen-compounds exceed those of the chlorine-compounds.

The atomic (or molecular) heat of any body which is contained in a compound, or may be assumed as one of its constituents, may accordingly be ascertained indirectly, by deducting from the molecular heat of the compound that of whatever other constituents it contains in addition to the body in question. For instance, if we deduct from the molecular heat of a compound of the form $M^{VI}M''O^4$ (chromate of lead, tungstate of calcium, &c.)—which, it may be remarked, is twice as great as that of compounds of the form $M^{IV}O^2$ (stannic oxide, titanic anhydride, &c.)—the molecular heat of the base M''O, we get as remainder the molecular heat of the anhydrous acid $M^{VI}O^3$; and the same remainder is obtained by deducting, from the molecular heat of acid chromate of potassium, $K^2Cr^2O^7$, that of the neutral chromate, K^2CrO^4. Again: the molecular heats of hydrated compounds admit of being regarded as made up of the molecular heat of the respective anhydrous substances, together with that of the water contained in them in the solid form.

Such indirect determinations of the atomic heat of a substance are nevertheless somewhat uncertain: not only because it occasionally happens that analogous compounds, which there is every reason to expect would possess equal molecular heats, do nevertheless, according to the experimental determinations of their specific heats, show important differences in their molecular heats; but also, and more particularly, because the total uncertainty attaching to the determination of the molecular heat, both of the original compound and of the element or group which has to be deducted from it, is accumulated upon the relatively small remainder. But when such inferential determinations are made for whole series of corresponding bodies, and not merely for individual cases, the results may be regarded as sufficiently trustworthy to render such considerations as arise from them worthy of notice.

This is especially the case with regard to the inferred specific and atomic heats of certain elements. As already pointed out, nearly all the elements, when examined in the solid state, are found to have approximately the same atomic heat—on the average, about 6·4. It is now very generally admitted that this—the so-called law of Dulong and Petit—holds good for *all* the elements, and a scale of atomic weights of the elements is considered as satisfactorily established if the products of these atomic weights into the specific heats are nearly equal. In the case of some elements, however, it results, both from the older determinations of their specific heats and from Kopp's newer determinations, that this rule is inapplicable; for example, the specific heats of carbon, boron, and silicon, are such, that the products, obtained by multiplying them into the respective atomic weights—when any values are adopted for these which can possibly be deduced from chemical considerations—are always decidedly smaller than the corresponding products in the case of other elements whose specific heats in the solid state can be investigated.

But these exceptional or accidental results acquire additional interest when taken in connection with the conclusions which may be drawn from the molecular heats of compounds. Compounds of those elements which obey Dulong and Petit's law exhibit a regularity in their molecular heats (*A. H.*): such, namely, that these are as many times greater than that of an element, as there are elementary atoms contained in the respective compounds (that is to say, $\frac{A.H.}{n} = 6{\cdot}4$ nearly, if n denotes the number of elementary atoms in one molecule of each compound). This regularity appears, not only in alloys containing atomic proportions of different metals, but also in the metallic chlorides, bromides, and iodides (see table, pp. 31, 32), and has been found by Kopp to extend likewise to compounds of which one molecule contains as many as seven, or even nine, elementary atoms (such as ZnK^2Cl^4 and PtK^2Cl^6). It is less distinctly recognisable in the case of the compounds of the metals with sulphur ($\frac{A.H.}{n}$ is here usually less than 6), and no longer exists for the metallic oxides, which, almost without exception, give for the quotient $\frac{A.H.}{n}$ a number decidedly less than 6, and smaller in proportion as the number of oxygen-atoms exceeds that of the atoms of metal. For water, considered of course in the solid state, this quotient is only about 3, and for the few organic compounds which Kopp has examined (such as tartaric acid and cane-sugar) it is still less.

The fact that this regularity is absent in so many compounds admits of only one explanation—namely, that they contain elements which, at least in these combinations, possess a different atomic heat from that which corresponds to Dulong and Petit's law.

It has often been assumed that the specific, and therefore the atomic, heat of an ele-

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ment may be different in certain compounds from what it is in the free state, and that it may be different in one compound from what it is in another. But, according to Kopp, the only ground for such an assumption is that by means of it the calculated molecular heats of compound bodies can be brought into closer agreement with the results of experiment; for, as he remarks, the variations which the specific heat of an element must be supposed capable of undergoing when it enters into combination (if Dulong and Petit's law be taken as applicable to all elements in the free state) are much greater than the variations, dependent on differences of physical condition, which have ever been actually observed in the case of an accurately investigated element. On the contrary, it appears that, in many compounds, the elementary atoms of which they are composed retain the atomic heats which belong to them in the free state; and that, moreover, the atomic heats which can be indirectly calculated for certain elements, notwithstanding their disagreement with Dulong and Petit's law, accord very closely with the atomic heats which result from the direct investigation of the same elements in the free state. Kopp accordingly maintains that—although these last-mentioned facts render the calculation of the molecular heat, and thence of the specific heat, of compound bodies from the atomic heats of the elements much more difficult, and although they make the agreement between the results of calculation and those of direct observation much less complete—every element, when considered in the solid state, and at a temperature sufficiently removed from its melting point, possesses one essentially invariable specific heat, which it is true may vary somewhat with differences of physical condition—such as greater or less density, amorphous or crystalline structure, &c.—but not to such an extent as some of his determinations of specific heat would require, if Dulong and Petit's law were really applicable to all the elements; and further, that the specific heat of each element in the free state is essentially the same as that which it possesses in its compounds.

By deducting from the molecular heats of the various oxides the atomic heats of the metals contained in them, or by deducting from the molecular heats of the oxygen-salts those of the groups which are therein united with oxygen (taking away from the molecular heat of $KClO^3$, for example, that of KCl, or from that of $PbSO^4$ the molecular heat of PbS), a remainder is obtained in every case which gives for the atomic heat of oxygen a number less than 6. For the reasons already stated (p. 38), the results thus arrived at do not agree so well as might be wished; nevertheless, Kopp gives it as his opinion that the atomic heat of oxygen cannot differ greatly from 4.

When the molecular heats of the carbonates M^2CO^3 and $M''CO^3$ are compared with the molecular heats of the oxides $(M'')^2O^3$ $(=3M''O)$ and $(M''')^2O^3$, the molecular heats of the carbonates are found to be decidedly smaller (according to Regnault's experiments, as given in the table, pp. 31–33, the molecular heats of the carbonates M^2CO^3 and oxides $3M''O$ are, on the average, about 29·4 and 32·85 respectively; those of the carbonates $M''CO^3$ and oxides $(M''')^2O^3$, about 21·7 and 25·5 respectively). Such comparisons show that the atomic heat of carbon in these combinations must be assumed to be about the same as that which has been directly found for free carbon in the form of diamond; namely, 1·8. Similar comparisons applied to other elements lead likewise to the adoption of atomic heats which are much smaller than what would correspond to the law of Dulong and Petit: for instance, to the atomic heat 2·3 (nearly) for hydrogen; for boron, to a number lying between 2 and 3; for silicon, to 4 (nearly); and for fluorine, also to a number which appears to be distinctly less than 6·4.

The specific and molecular heats of compound bodies calculated with the atomic heats thus arrived at for the elements, show, in very many cases, a very satisfactory degree of agreement with those deduced from direct experiment; in many other cases, however, they show important discrepancies. But equal discrepancies may likewise be observed among the molecular heats of analogous compounds, such even as contain elements as corresponding constituents which, when examined in the free state, gave nearly equal atomic heats. Regnault not unfrequently found this difference amount to one-tenth of the molecular heats in question; occasionally it was still greater.

Kopp considers that the results of his investigation confirm and widen the conclusion, already adopted by some philosophers, that Dulong and Petit's law does not hold good for all the so-called elements in the solid state. For a particular group of elements it is undoubtedly true; but if it is not a universal law, and if there are some elements to which it certainly does not apply, it may be considered doubtful with regard to individual elements, whether they ought to be looked upon as agreeing with or as departing from it. This may be said to be the case with sulphur, for which Kopp's determinations, made between 47° and the temperature of the atmosphere, give the atomic heat 5·2, nearly, which likewise agrees with the atomic heat of sulphur as indirectly deduced from the molecular heats of the metallic sulphides.

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In general, the molecular heat of a compound increases with its degree of complexity, or with the number of elementary atoms contained in one molecule, and this more especially in the case of such as contain only elements which follow Dulong and Petit's law. Kopp points out that if the application of this rule be extended to the elements themselves, the fact that a large proportion of them have nearly the same atomic heat may be taken as an indication that, whether they be absolutely simple substances or no, they are at least bodies of a comparable degree of complexity; while, on the other hand, the smaller atomic heats of some elements would seem to show that they are of a lower degree of complexity, or approach more nearly to truly simple bodies, than the rest. It would thus appear to be possible for a substance which can be proved to be compound, to have the same atomic heat as a so-called element: for instance, a peroxide, XO, containing an element whose atomic heat was equal to that of hydrogen, namely, about 2·3, would have a molecular heat of about 2·3 + 4 = 6·3, that is to say, the same as that of chlorine, iodine, or the metals.

With regard to the apparent improbability of two so-called elements, which are capable of mutually replacing each other in compounds, like hydrogen and the metals—or which even appear as corresponding constituents of isomorphous substances, like silicon and tin—having unequal atomic heats, it must be borne in mind that this is not in reality any more surprising or improbable than that an undecomposible substance and one known to be compound, such, for example, as hydrogen and peroxide of nitrogen, or potassium and ammonium, should replace each other in compound bodies without causing any alteration in their chemical characters, or should even be capable of appearing as corresponding constituents of isomorphous substances.

It still remains to consider, rather more particularly than has been done thus far, what it is that is measured under the name of the specific heat of solid, liquid, or gaseous substances, by the methods above described.

In all these methods of measurement, the heat imparted to the various bodies does something more than merely raise their temperature: it causes at the same time, as will be seen by what follows, an expansion or increase of their bulk; and when the bodies are again cooled, they contract, or diminish in bulk, to an equal amount. Hence the specific heats, measured as above, are not, strictly speaking, the relative quantities of heat required to raise the temperature of the various substances to the same extent, but the quantities required to do this, *and* at the same time to cause a greater or less increase of bulk. It is therefore a question for further investigation, what proportion of the total specific heat of a substance goes to raise its temperature, and what proportion to cause it to expand, or possibly to modify it in other ways.

The expansion which accompanies a given rise of temperature is inconsiderable in the case of solids and liquids, compared with that which takes place in gases; but it would be incorrect to conclude that the proportion of the total specific heat of solid, liquid and gaseous substances respectively, which is expended in causing expansion, is in proportion to the amount of expansion actually produced in each case. On the other hand, although no data exist which make it possible to form a very definite estimate of the ratio of the *real* specific heat to the *total apparent* specific heat of solids or liquids (see, however, p. 44), it is certain that they oppose a much greater resistance to any force tending to alter their bulk than gases do, and hence the comparatively small amount of expansion which they undergo may require the expenditure of as much or more heat than the relatively great expansion which takes place in gases: there is, therefore, no reason to believe that the ratio of the two specific heats, in the case of solid and liquid substances, is a magnitude of a different order from what it is in the case of gases.

The ratio of the apparent to the real specific heat of a gas, is the ratio of its specific heat under constant pressure (when, therefore, it expands as the temperature rises) to its specific heat when kept at a constant volume. It is, of course, the specific heat under constant pressure which is determined by the method already described (p. 29), and which is given for several gases in one of the preceding tables (p. 35). That the specific heat of a gas kept at a constant volume is less than its specific heat under a constant pressure, is obvious from the following considerations. Suppose a quantity of gas to have had its temperature raised t°, while the pressure to which it was exposed remained constant: the increase of temperature will have been accompanied by a corresponding increase of volume. Now, suppose the gas to be compressed, so as to restore it to its original bulk: the result of this compression will be to raise its temperature t'° more. The gas will now be in the same condition as it would have been if the same quantity of heat had been imparted to it without its being allowed to expand: hence it is evident that the same quantity of heat that is required to raise the temperature of a given weight of gas t°, while the pressure remains constant, will suffice to raise the temperature of the gas $t + t'$ degrees if it

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is kept at a constant volume. The specific heat, c', corresponding to a constant pressure, is therefore to the specific heat, c, corresponding to a constant volume, as $t + t'$ to t. One gramme of air has its temperature raised 1° C. when there is imparted to it 0·2374 of a unit (gramme-degree) of heat, and it expands at the same time, if the pressure remains unaltered, by $\frac{1}{273}$ of its bulk at 0° C. Accordingly, if the elevation of temperature consequent on compressing a gas by $\frac{1}{273}$ of its bulk at 0° be $a°$, it is evident that the ratio

$$\frac{1 + a}{1} = \frac{c'}{c} = k$$

is the ratio of the specific heat under constant pressure to that at constant volume. Clement and Desormes found by direct experiments upon air the value 0·34° for a, but it is plain that the unavoidable loss of heat attending such experiments must cause the result to be too low.

A less direct, but far more accurate means of determining the ratio $k = \frac{c'}{c}$, not only for air but for several other gases also, is afforded by the theory of the propagation of sound. The velocity with which a wave-motion, such as that which constitutes sound, is propagated through a homogeneous medium whose elasticity is the same in all directions, depends only upon the elasticity, e (see ii. 370), and the density, d, of the medium, according to the equation

$$v = \sqrt{\frac{e}{d}}.$$

This expression, applied to the movement of a sound-wave through the air, becomes

$$v = \sqrt{\frac{e}{d}} = \sqrt{\frac{gH\sigma}{s} \cdot k\,(1 + a\,t)};$$

where g denotes the accelerating force of gravity (= 9·808 metres = 32·18 feet); H = 760 mm. = 29·92 inches; σ the weight of 1 cub. cent. of mercury at 0° = 13·596 grm.; s the weight of 1 cub. cent. of air at 0° and under a pressure of 760 mm. mercury = 0·001293 grm.; t the temperature of the air, a its coefficient of expansion under constant pressure (= 0·00367), and k the required ratio $\frac{c'}{c}$. Now the velocity of sound in air at 0° has been experimentally found to be = 333 metres, or 1092·6 feet per second; hence the above equation gives

$$333 = \sqrt{\frac{9·808 \times 0·76 \times 13·596}{0·001293} \cdot k}$$

or k = 1·414.

The physical reason for the presence of the magnitude k in the formula for the velocity of sound, is that that velocity, being dependent upon the elasticity of the air, varies with every variation of the elasticity, and that the alternate heatings and coolings, caused respectively by the alternate condensations and rarefactions which constitute the waves of sound, are equivalent, in their effect upon the velocity of transmission of the waves, to an increase in the elasticity of the air in the proportion of $1 : k = 1 : 1·414$.

In the above formula the magnitudes g, H, σ t, and a are all independent of the particular nature of the gas (at least in the case of perfect gases; for imperfect gases the value of a varies slightly), hence if v and v' represent the velocities with which sound traverses two different gases, s and s' their densities, and k and k' the ratios of the two specific heats of each, we have

$$v : v' = \sqrt{\frac{k}{s}} : \sqrt{\frac{k'}{s'}},$$

or

$$\sqrt{k'} = \frac{v'}{v}\sqrt{\frac{s'}{s}} \cdot k;$$

so that the ratio k' for any gas may be deduced from that of air, provided the density of the gas and the velocity with which it is traversed by sound are known.

Hence the investigation of this ratio is reduced to that of the real velocities of sound in different elastic fluids. For any other gas than atmospheric air, it is useless to think of measuring directly the velocity of propagation of a sonorous wave; recourse must obviously be had to indirect means. The theory of wind instruments suggested a mode, which was first indicated and put in practice by Chladni and Jacquin. This method consists in making the same pipe, with a flute *embouchure*, sound successively with all the elastic fluids, supposed at the same temperature, and in determining the

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pitch of tone given by each gas. Admitting that the fluid column contained in the instrument experiences the same mode of subdivision in every case—that it corresponds, for example, to what is called the fundamental sound, or the gravest of all those which the theory of Bernouilli indicates for the same pipe, we easily come to know the length of a wave, and its duration in each elastic fluid; and consequently the velocity with which a vibration would be propagated in each of them.

The following table exhibits the results of Dulong's researches on this subject. (Ann. Ch. Phys. xli. 113):

Names of the elastic fluids.	Tones given by the same pipe 60 centim. long.	Number of vibrations in a sexagesimal second.	Temperature by the centigrade therm.	Numbers adopted in the calculation for the density of the fluid.	Velocity of the propagation of sound at 0°, deduced from the tone given by each fluid.	Ratio of the specific heats at a constant pressure, to the specific heat at a constant volume, $= k$.
Air . . .	ut_1 med.	500·4	22°	1	333m	1·421
Oxygen . .	$+si_{-1}$	474·9 475·2 474·5	21	1·1026	317·17	1·415 1·417 1·413
Hydrogen .	$-si_2$	1883·6 1881·	17	0·0688	1269·5	1·409 1·405
Carbonic anhydride	sol_{-1}	393·18 392·68	22 20·5	1·524	261·6	1·357 1·340
Carbonic oxide	ut_1	501·3 503·07	15	0·974	337·4	1·423 1·433
Nitric oxide .	sol_{-1}	392·7	20·5	1·527	261·9	1·343
Olefiant gas .	$-si_{-1}$	466·9	16	0·981	314	1·240

The slight difference between the value 1·421, obtained by Dulong for the ratio of the two specific heats of air, and the number 1·414 already given is, in part, due to the changes which have taken place, since the date of his experiments, in the adopted value of the constants which enter into the calculation.

Theoretical views of the nature of heat and the constitution of gaseous bodies, which will have to be further considered in a subsequent part of this article, lead to the conclusion that, for all perfect gases, the difference between the two specific heats of a unit of volume is expressed by the equation

$$\gamma' - \gamma = A \frac{p}{a + t} \quad . \quad . \quad . \quad . \quad . \quad (a)$$

where A is a constant (the thermal equivalent of the unit of work), p and t the pressure and temperature of the gas, and $\frac{1}{a}$ the coefficient of expansion, and therefore $a = 273$ nearly. The right hand member of this equation contains nothing which depends on the particular nature of the gas to which it is applied; and hence, if the temperature and pressure are taken the same for all gases, the difference $\gamma' - \gamma$ will be the same for all. If the values of γ' and γ applicable to atmospheric air be distinguished as γ_1', and γ_1, we have

$$\gamma' - \gamma = \gamma_1' - \gamma_1,$$

an equation which remains true whatever unit of volume is adopted, and therefore also, if with Regnault, we take this unit to be the volume occupied by a unit of weight of air at the same temperature and pressure as the gas under consideration. Therefore

$$\gamma' - \gamma = \gamma_1' - \gamma_1 = 0{\cdot}2374 - 0{\cdot}1680 = 0{\cdot}0694 \text{ and } \gamma = \gamma' - 0{\cdot}0694.$$

By means of this equation, the specific heats of the various gases under constant volume may be calculated from their specific heats under constant pressure as given in the table on p. 35. The numbers so obtained will refer to the unit of volume adopted by Regnault; to deduce therefrom the specific heats which correspond to a *unit of weight*, these numbers require merely to be divided by the densities of the respective gases; and to obtain the specific heats *compared with that of an equal volume of air*, they must be divided by 0·1680.

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According to equation (*a*) the quotient $\frac{\gamma'}{\gamma} = k$ becomes

$$k = 1 + \frac{A}{\gamma} \cdot \frac{p}{a + t}$$

and it therefore exceeds unity by a quantity which is inversely proportional to γ.

Further, the general considerations above referred to make it probable that the true specific heat of equal volumes of all simple gases is the same, and that the specific heat of compound gases is equal to that of the simple gases multiplied by the fraction which represents their molecular condensation (*e.g.* for hydrochloric acid the multiplier would be $\frac{1+1}{2} = 1$, for water $\frac{2+1}{2} = 1{\cdot}5$, for ammonia $\frac{3+1}{2} = 2$, &c.).

The following table, which is copied with very slight modifications from tables given by Clausius (Ann. Ch. Pharm. cxviii. 118) and Buff (*ibid.* cxv. 312; see also pp. 306, 307), and may be considered supplementary to the table on p. 35, gives the results of the application of these formulæ to the gases and vapours which were the

I. Name of gas.	II. Formula.	III. Density.	IV. Sp. heat of equal volumes under constant pressure Air=1.	V. Specific heat at constant volume. Equal weights. Water = 1.	VI. Specific heat at constant volume. Equal volumes. Air=1.	VII. Value of $\frac{c'}{c} = k$.	VIII. True sp. heat compared with that of the elementary gases.
Air		1·0000	1·00	0·168	1·00	1·413	1·0
Oxygen	O^2	1·1056	1·01	·155	1·02	1·403	1·0
Nitrogen	N^2	·9713	1·00	·173	1·00	1·409	1·0
Hydrogen	H^2	·0692	·99	2·406	·99	1·417	1·0
Chlorine	Cl^2	2·4502	1·25	·093	1·35	. .	1·0
Bromine	Br^2	5·4772	1·28	·043	1·39	. .	1·0
Nitric oxide	NO	1·0384	1·01	·165	1·02	1·403	1·0
Carbonic oxide	CO	·9673	1·00	·173	1·00	1·416	1·0
Hydrochloric acid	HCl	1·2596	·98	·130	·98	. .	1·0
Nitrous oxide	N^2O	1·5241	1·45	·180	1·64	1·243	1·5
Water	H^2O	·6219	1·26	·369	1·36	1·302	1·5
Sulphydric acid	H^2S	1·1747	1·20	·184	1·29	. .	1·5
Carbonic anhydride	CO^2	1·5201	1·39	·171	1·55	1·265	1·5
Sulphurous anhydride	SO^2	2·2113	1·44	·123	1·62	. .	1·5
Sulphide of carbon	CS^2	2·6258	1·74	·131	2·05	. .	1·5
Ammonia	NH^3	·5894	1·26	·391	1·37	. .	2·0
Marsh-gas	CH^4	·5527	1·38	·467	1·54	. .	2·5
Olefiant gas	C^2H^4	·9672	1·65	·332	1·91	1·144	3·0
Alcohol	C^2H^6O	1·5890	3·02	·408	3·86	. .	4·5
Ether	$C^4H^{10}O$	2·5573	5·18	·454	6·91	1·059	7·5
Sulphide of ethyl	$C^4H^{10}S$	3·1101	5·29	·378	7·00	. .	7·5
Chloride of ethyl	C^2H^5Cl	2·2269	2·57	·242	3·22	. .	4·0
Bromide of ethyl	C^2H^5Br	3·7058	2·96	·171	3·77	. .	4·0
Cyanide of ethyl	C^3H^5N	1·9021	3·41	·332	4·41	. .	4·5
Chloroform	$CHCl^3$	4·1244	2·72	·140	3·43	. .	2·5
Chloride of ethylene	$C^2H^4Cl^2$	3·4174	3·30	·209	4·25	. .	4·0
Acetate of ethyl	$C^4H^8O^2$	3·0400	5·13	·378	6·84	. .	7·0
Acetone	C^3H^6O	2·0036	3·48	·378	4·50	. .	5·0
Benzene	C^6H^6	2·6943	4·26	·350	5·61	. .	6·0
Oil of turpentine	$C^{10}H^{16}$	4·6978	10·01	·491	13·74	. .	13·0
Trichloride of phosphorus	PCl^3	4·7464	2·69	·120	3·39		
Chloride of arsenic	$AsCl^3$	6·2667	2·95	·101	3·76		
Chloride of silicon	$SiCl^4$	5·8833	3·28	·121	4·22		
Stannic chloride	$SnCl^4$	8·9654	3·54	·086	4·59		
Chloride of titanium	$TiCl^4$	6·6402	3·61	·119	4·68		

subject of Regnault's experiments. Column I. gives the *names* of the gases; column II. their *chemical composition:* the formulæ in this column represent *two* volumes of the several gases: hence the molecular condensation of each gas is obtained by dividing the number of atoms in its formula by 2. Column III. gives the *densities*

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adopted by Regnault in his calculations. Column IV. gives the specific heats under *constant pressure* compared with that of an equal volume of air taken as unity. The numbers in this column are obtained from those in the last column of the table on p. 35 by dividing each by 0·2374 = specific heat of air under constant pressure. Columns V. and VI. contain the specific heats corresponding to a *constant volume* compared (V.) with that of an equal weight of water, and (VI.) with that of an equal volume of air. Column VII. gives the *ratio of the two specific heats* for some of the most important gases, obtained by dividing the specific heats of equal weights under constant pressure, as given in the previous table (p. 35), by the corresponding values in column V. of this table. Column VIII. contains the theoretical *true specific heats*, compared with the true specific heat of an equal volume of air or any simple gas. These numbers are calculated upon the supposition that the true specific heats of the elementary gases are the same in the combined as in the uncombined state.

On comparing the numbers in columns VI. and VIII. it will be seen that there is, on the whole, an unmistakable correspondence between them, but that they exhibit also in many cases decided discrepancies. These are probably due, in part to errors of experiment, and in part to the fact that the method, by which the numbers representing the specific heats at constant volume are calculated from those representing the specific heats at constant pressure, is quite accurate only in the case of perfect gases; and further that, even if the numbers in column VI. represented the specific heats for constant volume with perfect accuracy, these numbers would not necessarily agree with those in column VIII., except for perfect gases.

The true specific heat of a gas, that is, its specific heat under a constant volume, is regarded by Clausius (Phil. Mag. [4] xxiv. 204, 205) as the true specific heat of the substance in all states of aggregation, and in the combined as well as the free state. Rankine, on the other hand (*A Manual of the Steam Engine*, &c., p. 307), while admitting that the true specific heat of each substance remains constant at all densities, so long as the substance retains the same condition, solid, liquid, or gaseous, supposes that a change of real specific heat, sometimes considerable, often accompanies the change between any two of these conditions. But, as Clausius has pointed out (*loc. cit.*; also Pogg. Ann. cxx. 438), there is no obvious reason why the real specific heat of a body should be supposed to undergo alteration on the passage from one state of aggregation to another, if it remains constant within the same state of aggregation; for the changes of density and elasticity, which accompany changes of temperature within one and the same state, do not differ in kind, but only in degree, from those which constitute the passage from one state to another. Assuming, therefore, that the specific heat under constant volume of a substance in the gaseous state is its real specific heat under all conditions, we have, for water, for instance,

Ratio of apparent to real specific heat in the *solid state* (between $-20°$ and $0°$) . . . . . $= \frac{\cdot 504}{\cdot 369} = 1\cdot 367$

Ratio of apparent to real specific heat in the liquid state (between $0°$ and $100°$) . . . . . $= \frac{1\cdot 008}{\cdot 369} = 2\cdot 732$

Ratio of apparent to real specific heat in the gaseous state . $= \frac{\cdot 4805}{\cdot 369} = 1\cdot 302$

2. *Changes of Volume produced by Heat.*

It is an almost universal law that, when heat is imparted to any body, the body expands or augments in bulk, unless prevented from doing so by a corresponding increase of external pressure, and that any body from which heat is withdrawn contracts or diminishes in bulk. The exceptions to this law are extremely few, and occur only within particular limits of temperature: the most important will be specially pointed out hereafter. Admitting the atomic hypothesis of the constitution of matter, it is impossible to conceive of expansion otherwise than as a movement of the molecules of a mass, which has for its effect to increase their mean distance from each other. Hence when heat causes a body to expand, it acts in opposition to the forces which tend to prevent the further separation of the molecules; and the bulk of the body at any given temperature is the result of an equilibrium between these forces and the expansive force of the heat contained in it at that temperature. The forces by which the particles of a mass are held together consist in part of the pressure to which it is subjected from without, and partly of the pressure arising from the mutual attractions of the particles themselves. This latter pressure, which is known as cohesive force, has a much greater effect in determining the bulk of solid and liquid

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bodies than any pressure which acts upon them from without, and it varies not only in different bodies, but even in the same body its value is different at different temperatures. Hence it is not surprising that the relations subsisting between the temperature and bulk of solid and liquid substances should be somewhat complex. In perfect gases, however, cohesion does not exist, and hence the only opposing force which heat has to overcome in order to cause them to expand is the external pressure. Consequently it is found that the rate of expansion of gases bears a much more simple relation to the heat by which it is caused, than that observed in solid and liquid bodies. It is, therefore, convenient to consider the laws of the expansion of gaseous substances before examining those which regulate the expansion of matter in the two other states of aggregation.

Expansion of Gases.—In a perfect gas, volume, elasticity, and temperature would be related to each other in the manner expressed by the equation

$$pv = J(a + t), \quad . \quad . \quad . \quad . \quad . \quad . \quad (a)$$

where v is the volume of a given weight of the gas at the temperature t and under the pressure p, and J and a are constants. Hence, if v' were the volume of the same weight of the same gas corresponding to any other pressure, p', and temperature, t', we should have

$$\frac{p\ v}{p'v'} = \frac{a + t}{a + t'} \quad . \quad . \quad . \quad . \quad . \quad (b)$$

No absolutely perfect gas, however, is known in nature, so that, according to the best experiments, the values of a which correspond to different values of p, v, and t, are not quite constant, but vary slightly, not only with variations of these factors, but also according to the nature of the gas. The properties of air, however, and the other non-condensable gases accord so nearly with the above formulæ—which are in fact nothing more than a statement of the laws of Boyle and Gay-Lussac (Gases, ii. 819*)—that, except in cases where extreme accuracy is required, the accord may be considered perfect.

If in the above equation (b) we make $p = p'$ we get

$$\frac{1}{a} = \frac{v - v'}{v't - vt'}; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (c)$$

that is, $\frac{1}{a}$ is the *coefficient of expansion of the gas under constant pressure*, or the amount by which that quantity of gas which occupies a unit of volume at 0° C. expands, under constant pressure, when its temperature is raised one degree. Similarly, by making $v = v'$, we have

$$\frac{1}{a} = \frac{p - p'}{p't - pt'}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (d)$$

or $\frac{1}{a}$ is also the *coefficient of expansion of the gas under constant volume*, or, more correctly (since when $v = v'$ no actual expansion can take place), $\frac{1}{a}$ is the coefficient of increase of elasticity, or the increment of elasticity, under a constant volume, for a rise of temperature of one degree, of a gas whose elasticity at 0° C. is unity. For a perfect gas, it is obvious that these two values of $\frac{1}{a}$ would be equal.

The first tolerably accurate determinations of the coefficients of expansion of gaseous bodies were made by Gay-Lussac. He used in his experiments a vessel shaped much like a thermometer, having a bulb about 1 centimetre in diameter, and a tube about 30 or 40 centimetres long, and 1 or 1·5 millimetres wide. The tube was divided into lengths of equal capacity, and the proportion between the total capacity of the bulb and that of one division of the tube was accurately determined. The apparatus having been filled with air dried by passing through a chloride-of-calcium tube, a drop of mercury, occupying a short length of the divided tube, was employed to cut off the enclosed air from communication with the atmosphere, and at the same time to serve as an index whereby to read off its volume. The bulb was then fixed, with the stem horizontal and projecting through the side, in a vessel filled with water, through the medium of which it could be heated to various temperatures. The volumes occupied by the air at each temperature could be read off upon the divided tube by noting the position of the little column of mercury; but the volumes thus determined required to be corrected (a) for the

* Equation (b) may obviously be put into the form $v = v' \frac{p'}{p} \cdot \frac{a + t}{a + t'}$, and is then identical with that by which these laws are represented at the place quoted.

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expansion of the glass, (*b*) for the lower temperature of the portion of air contained in the part of the tube outside the water-bath, and (*c*) for the possible alterations of barometric pressure during the experiment. Independently of these latter alterations, which were always very inconsiderable, the pressure upon the gas remained constant during the experiment: it was the volume which changed. Applying the same method to other gases and to vapours, Gay-Lussac concluded that all gases and vapours (at temperatures sufficiently removed from their points of liquefaction) expanded by heat to the same extent; that, namely, when heated from 0° to 100° C. they expanded in the proportion of 1 : 1·375, or for 1° C. by 0·00375 = $\frac{1}{267}$ of their volume at 0°.

The confidence which these results naturally excited, in consequence of the high reputation of the author, was still further increased by the confirmation which they received at the hands of Dulong and Petit, and also because it was considered probable, on theoretical grounds, that in substances in which cohesive force no longer existed, the expansive action of heat should be independent of chemical composition. Hence, when the Swedish physicist Rudberg announced, as the result of his own more accurate experiments, that the coefficient of expansion found by Gay-Lussac was considerably too high, the statement was at first received with hesitation.

Rudberg determined the value of the coefficient of expansion of air $\left(\frac{1}{a}\right)$ between 0° and 100° C. by two series of experiments. In the first he determined the contraction undergone by a given quantity of air on cooling from 100° to 0° under a nearly constant pressure; in the second, the difference in the elastic force at 0° and 100° of a quantity of air kept at the same volume at the two temperatures. Making t and t' in equations (*c*) and (*d*) respectively = 100 and 0, the results of his experiments may be stated as follows:—The mean of twelve experiments by the first method gave for the coefficient of expansion under constant pressure—

$$\frac{1}{a} = \frac{v - v'}{100v'} = 0{\cdot}003648 = \frac{1}{274};$$

the mean of ten experiments by the second method gave for the coefficient of expansion at constant volume—

$$\frac{1}{a} = \frac{p - p'}{100p'} = 0{\cdot}003646 = \frac{1}{274},$$

a result identical with the preceding.

More recently (1841) the expansion of air and other gases has been again made the subject of elaborate experiments by Regnault (*Relation des Expériences . . . . pour déterminer les principales lois et les données numériques qui entrent dans le calcul des Machines à Vapeur*, Mém. Acad. Roy. des Sciences, xxi. 1–120 (1847); also Ann. Ch. Phys. [3] iv. 5 and v. 52) and by Magnus (Pogg. Ann. lv. 1, and lvii. 177).

Regnault made five series of experiments by methods more or less distinct. His first method was the same as the first method employed by Rudberg. It consisted in heating a cylindrical glass vessel of known capacity, about 2·5 or 3 centimetres wide, and about 11 centimetres long, filled with dry air, to 100°; sealing it hermetically at that temperature; then cooling it to 0°, and observing the quantity of mercury which entered on breaking off the point of the instrument under the surface of that metal. The apparatus employed and the method of experimenting were, in fact, exactly the same as in determining a temperature by means of the air-thermometer in the manner already described (pp. 19 and 20): for it is obvious that the same experiment which, the coefficient of expansion of air being known, serves to determine the temperature at which the air-thermometer is sealed, would, if this temperature were known, serve for the determination of the coefficient of expansion.

The second set of determinations were made by a method only slightly different from the first, the only essential difference in the apparatus being that the tube connected with the air-reservoir was about 40 centimetres (16 inches) long, and that a portion of it, about two inches long and separated from the air-reservoir by about four inches, was wide enough to produce only a very slight capillary depression in a column of mercury. The effect of this modification of the apparatus was that when, after being heated to 100° and sealed at that temperature, the instrument was placed with the tube pointing vertically downwards and with the point dipping into mercury, the mercury rose only as far as the wide part of the tube, on breaking off the point, and did not reach the reservoir at all. Hence the space occupied by the air at zero differed from that which it had occupied at 100°, only by the capacity of that portion of the tube which became filled with mercury on opening the point; and since the diameter of the tube was, with the exception of the wider portion already mentioned, very small, this capacity bore a small proportion to the total capacity of the instrument. The experiment consisted therefore essentially in a determination of the difference of the elastic force of the air at the two temperatures.

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In the third and fourth sets of experiments, the air-reservoir was made to communicate with a manometer, whereby the pressure upon the enclosed air could be varied at will and accurately measured. The pressures were so regulated that the air was caused to occupy accurately the same volume at 0° and 100°, and the differences of pressure required were determined. The apparatus for the third series of experiments was copied, with some improvements of detail, from that employed by Rudberg in his second series. The apparatus for the fourth series was the same in principle, but its construction was such that the pressure upon the air could be determined with still greater accuracy than was possible with the preceding apparatus.

In the fifth set of experiments, the pressure upon the air remained constant, and the alteration of volume was determined by weighing the quantity of mercury which filled the space into which it expanded.

The mean results of numerous experiments made by each of these processes were as follows:—If p_0 and v_0 represent respectively the pressure and volume of the air at 0°, and p_1 and v_1 its pressure and volume at 100°, the value of $\frac{p_1 v_1}{p_0 v_0}$ was—

By the first series	1·36623
„ second series	1·36633
„ third series	1·36679
„ fourth series	1·36650
„ fifth series	1·36706

In the second, third, and fourth series, the expansion was calculated from the change of elastic force undergone by the same volume of air when its temperature changed between 0° and 100°; in the experiments made by the first method, both pressure and volume changed considerably, so that they gave a mixed result. From the consideration of all the experiments by the first four methods, Regnault adopts for the coefficient of expansion of air, under *constant volume*, for 1 degree centigrade between 0 and 100°, the number

$$0{\cdot}003665 = \frac{1}{272{\cdot}9} = \frac{1}{273} \text{ nearly.}^*$$

This result agrees precisely with that obtained by Magnus.

For the coefficient of expansion of air under *constant pressure*, Regnault adopts the number

0·00367

given by the experiments of the fifth series.

Similar experiments extended to other gases gave the mean results recorded in the following table, in which are also included the results obtained by Magnus:—

Table of Expansion of Gases *between* 0° *and* 100° *at Ordinary Pressures.*

Name of gas.	Value of $\frac{p_1 v_1}{p_0 v_0} = 1 + \frac{100}{a}$.		
	Constant volume.		Constant pressure.
	Regnault.	Magnus.	Regnault.
Hydrogen . . .	1·3667	1·3657	1·3661
Air	1·3665	1·3665	1·3670
Nitrogen . . .	1·3668		
Carbonic oxide . .	1·3667	. .	1·3669
Carbonic anhydride .	1·3688	1·3691	1·3710
Nitrous oxide . .	1·3676	. .	1·3719
Sulphurous anhydride .	1·3845	1·3856	1·3903
Cyanogen . . .	1·3829	. .	1·3877

The foregoing results are all deduced from experiments in which the gases operated upon were subject to pressures differing but little from the ordinary pressure of the atmosphere. In another investigation (*Op. cit.* pp. 96–120) Regnault determined the coefficients of expansion of air and some other gases at pressures considerably different from that of the atmosphere. The following table gives the mean results:

* If the coefficient of expansion of air be taken = 0·0036666 . . . . it may be represented by the vulgar fraction $\frac{11}{3000}$, a number which is very convenient for the purposes of calculation.

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Table of EXPANSION OF GASES *between* 0° *and* 100° *at Various Pressures.*

AIR.

Constant Volume.		*Constant Pressure.*	
Density. (Density of air at 0° and 760 mm. pressure = 1.)	$\frac{p_1}{p_0} = 1 + \frac{100}{a}$.	Pressure. mm.	$\frac{v_1}{v_0} = 1 + \frac{100}{a}$.
0·1444	1·36482	760	1·36706
0·4937	1·36572	2525	1·36944
1·0000	1·36650	2620	1·36964
2·2084	1·36760		
2·8213	1·36894		
4·8100	1·37091		

CARBONIC ANHYDRIDE.

Constant Volume.		*Constant Pressure.*	
Density. (Density of carbonic anhydride at 0° and 760 mm. pressure = 1.)	$\frac{p_1}{p_0} = 1 + \frac{100}{a}$.	Pressure. mm.	$\frac{v_1}{v_0} = 1 + \frac{100}{a}$.
1·0000	1·36856	760	1·37099
1·1879	1·36943	2520	1·38455
2·2976	1·37523		
4·7318	1·38598		

HYDROGEN.

Constant Pressure.	
Pressure. mm.	$\frac{v_1}{v_0} = 1 + \frac{100}{a}$.
760	1·36613
2545	1·36616

SULPHUROUS ANHYDRIDE.

Constant Pressure.	
Pressure. mm.	$\frac{v_1}{v_0} = 1 + \frac{100}{a}$.
760	1·3903
985	1·3984

The following general conclusions may be drawn from these results:

1°. The coefficients of expansion of air, hydrogen, nitrogen, and carbonic oxide, between 0° and 100°, are sensibly equal.

2°. The coefficients of expansion of the condensable gases, carbonic anhydride, nitrous oxide, sulphurous anhydride, and cyanogen, are slightly greater than the coefficient of expansion of the permanent gases. For the condensable gases also the coefficient of expansion (under constant pressure) slightly exceeds the coefficient of increase of elasticity (the gas being kept at constant volume), a difference which is likewise observed, though in a less degree, in the case of air.

3°. The coefficient for hydrogen is not influenced by a change of pressure from 1 to 3 atmospheres. The coefficients for air, carbonic anhydride, and sulphurous anhydride are greater at high densities and pressures than at low ones.

Notwithstanding the differences in the absolute values of the coefficients of expansion of air at different densities, and of air, hydrogen, and carbonic anhydride, Regnault found by direct experiments (*Op. cit.* pp. 171–190) that the elastic force of air, of any initial pressure at 0° between 400 mm. and 1300 mm., and the elastic force of hydrogen and carbonic anhydride increased according to the same law at all temperatures between 0° and 350° C. Hence gas-thermometers filled with air of any density, or with hydrogen, or carbonic anhydride, would give perfectly similar indications, provided that, in calculating the temperatures, the coefficient proper to each gas were employed. The coefficient of expansion of sulphurous anhydride was found to diminish, relatively to that of air, in proportion as the temperature rose, being 0·0038251 at 98·12° of the air-thermometer, and 0·0037893 at 310·31°.

Hence as a general conclusion: Although no gas appears to follow *absolutely* the law

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of expansion expressed by the equations (*a*) and (*b*), page 45, the permanent gases follow this law so closely that, in all except the most refined calculations, these formulæ may be taken as strictly applicable to them, the value of a being for all a number sensibly equal to 273.

The following consequences of these equations are of importance in calculating the changes of volume and elastic force of gases corresponding to given changes of temperature: Let v be the volume of a given weight of gas at 0° C., and p its elastic force at the same temperature; let v_1 and p_1 be the volume and elastic force of the same quantity of gas at any other temperature, t_1°; and let v_2 and p_2 be the volume and elastic force corresponding to any third temperature, t_2°: then, the volume at t_1, expressed in terms of the volume at 0°, will be—

$$v_1 = v\frac{p}{p_1}\cdot\frac{a+t_1}{a} = v\frac{p}{p_1}\cdot\left(1+\frac{1}{a}t_1\right),$$

or
$$v_1 = v\frac{p}{p_1}\cdot\frac{273+t_1}{273} = v\frac{p}{p_1}\cdot\left(1+\frac{1}{273}t_1\right) = v\frac{p}{p_1}\cdot\left(1+0{\cdot}003665\,t_1\right);$$

the volume at 0°, in terms of the volume at t_1°, will be—

$$v = v_1\frac{p_1}{p}\cdot\frac{a}{a+t_1} = v_1\frac{p_1}{p}\cdot\frac{1}{1+\frac{1}{a}t_1},$$

or
$$v = v_1\frac{p_1}{p}\cdot\frac{273}{273+t_1} = v_1\frac{p_1}{p}\cdot\frac{1}{1+\frac{1}{273}t_1} = v_1\frac{p_1}{p}\cdot\frac{1}{1+0{\cdot}003665\,t}$$

and the volume at t_2°, in terms of the volume at t_1°, will be—

$$v_2 = v_1\frac{p_1}{p_2}\cdot\frac{a+t_2}{a+t_1} = v_1\frac{p_1}{p_2}\cdot\frac{1+\frac{1}{a}t_2}{1+\frac{1}{a}t_1},$$

or
$$v_2 = v_1\frac{p_1}{p_2}\cdot\frac{273+t_2}{273+t_1} = v_1\frac{p_1}{p_2}\cdot\frac{1+0{\cdot}003665\,t_2}{1+0{\cdot}003665\,t_1}.$$

The elastic force at t_1°, in terms of the elastic force at 0°, will be—

$$p_1 = p\frac{v}{v_1}\cdot\frac{a+t_1}{a} = p\frac{v}{v_1}\cdot\left(1+\frac{1}{a}t_1\right),$$

or
$$p_1 = p\frac{v}{v_1}\cdot\frac{273+t_1}{273} = p\frac{v}{v_1}\cdot\left(1+\frac{1}{273}t_1\right) = p\frac{v}{v_1}\cdot\left(1+0{\cdot}003665\,t_1\right);$$

the elastic force at 0°, in terms of the elastic force at t_1°, will be—

$$p = p_1\frac{v_1}{v}\cdot\frac{a}{a+t_1} = p_1\frac{v_1}{v}\cdot\frac{1}{1+\frac{1}{a}t_1},$$

or
$$p = p_1\frac{v_1}{v}\cdot\frac{273}{273+t_1} = p_1\frac{v_1}{v}\cdot\frac{1}{1+\frac{1}{273}t_1} = p_1\frac{v_1}{v}\cdot\frac{1}{1+0{\cdot}003665\,t_1};$$

and the elastic force at t_2°, in terms of the elastic force at t_1°, will be—

$$p_2 = p_1\frac{v_1}{v_2}\cdot\frac{a+t_2}{a+t_1} = p_1\frac{v_1}{v_2}\cdot\frac{1+\frac{1}{a}t_2}{1+\frac{1}{a}t_1},$$

or
$$p_2 = p_1\frac{v_1}{v_2}\cdot\frac{273+t_2}{273+t_1} = p_1\frac{v_1}{v_2}\cdot\frac{1+0{\cdot}003665\,t_2}{1+0{\cdot}003665\,t_1}.$$

It is very important to bear in mind, with reference to all calculations of this kind, that when the coefficient of expansion of the permanent gases is said to be uniform at all temperatures, and equal to $\frac{1}{273}$, it is not meant that 1 vol. of a gas at any temperature, t_1°, becomes $1\frac{1}{273}$ vol. at the temperature $(t+1)$°; but that 1 vol. at 0° becomes $1\frac{1}{273}$ vol. at 1°, and $1+\frac{t}{273}$ vol. at t°, and that consequently 1 vol. at t° becomes $1+\frac{1}{273+t}$ at $(t+1)$°.

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The irregularities in the expansion of the more condensable gases, particularly sulphurous anhydride, which are brought to light by Regnault's experiments, are met with to a greater or less extent in the case of all liquefiable gases or vapours, and are more marked in proportion as the gases are examined nearer to their points of liquefaction. The law with regard to the expansion of vapours appears to be, that their coefficients of expansion are considerably greater than $\frac{1}{273}$ at temperatures near to the boiling points of the liquids from which they are formed, and that they continue to diminish as the temperature rises, so as to approach more and more closely to a constant value of nearly $\frac{1}{273}$. Hence, at sufficiently high temperatures, all vapours and liquefiable gases acquire the properties of sensibly perfect gases. The rapidity with which the coefficients of expansion of different vapours approach their limiting values, varies greatly. Some vapours, as that of ether, have a nearly uniform rate of expansion within twenty or thirty degrees of the boiling point of the liquid, whereas others show a sensibly diminishing rate of expansion throughout a much wider interval of temperature: for instance, acetic acid through upwards of 120 degrees, and sulphur-vapour through 400 degrees above the boiling point of sulphur. This property of vapours is of great importance in relation to the experimental determination of their densities. (For further details, see SPECIFIC GRAVITY; also ii. 811.) The fact of a vapour having reached a temperature at which its rate of expansion is the same as that of air, is indicated by its density, compared with that of air at the same temperature and pressure, remaining constant for any further rise of temperature: thus the density of acetic acid vapour (boiling point 118°) was found, by Cahours, to be,

at	125°,	150°,	180°,	200°,	240°,	270°,	310°,	336° C.,
=	3·180,	2·727,	2·438,	2·248,	2·090,	2·088,	2·085,	2·083.

That is to say, it expands more rapidly than air up to about 240°, but above that temperature its expansion is very nearly the same as that of air.

Relation between the Expansion of a perfect Gas and the Quantity of Heat required to produce it.—Equation (*a*) (page 45) may be written—

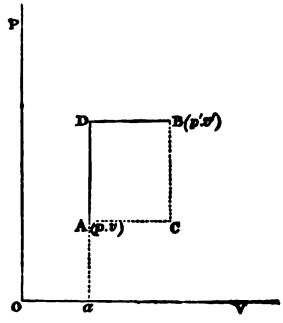
$$p v = m (1 + \alpha t), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (e)$$

if we put m for Ja, and α for $\frac{1}{a}$ = coefficient of expansion. Let the volume, v, be expressed in cubic metres, the pressure, p, in kilogrammes per square metre, and the temperature, t, in degrees of the centigrade thermometer. Then, since m is a constant, its value is independent of the variations of v, p, and t, and in order to find it, we may make any suppositions we please with regard to these factors. To determine its value, let p be the normal atmospheric pressure of 0·76 metre referred to 1 square metre, = 10,333 kilogr., let v be one cubic metre, and let t be 0° C. Then we see that m must be the atmospheric pressure on 1 square metre = 10,333 kilogr. = H, and we have—

$$p v = H(1 + \alpha t) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (f)$$

In *fig.* 533 let distances measured parallel to the axis of abscissæ, OV, represent volumes, and distances measured parallel to the axis of ordinates, OP, represent pressures. Then, since the condition of a gas is defined if p and v, two of the three variable quantities upon which it depends, are known, that condition may be represented by the position of a point relatively to the lines OP and OV. Let the point A represent the initial condition (p . v) of a gas: we will consider the quantities of heat which must be imparted to, or withdrawn from, the gas, in order to make it pass through the series of conditions represented by the sides of the rectangle ADBCA, parallel to OP and OV.

Fig. 533.



1. When the gas passes from the state A to the state D, its elastic force increases while its volume, v, remains unaltered; to produce this change, its temperature must be raised from t to the temperature t_1 which is given by the equation $p' v = H(1 + \alpha t_1)$, which, combined with (f), $pv = H(1 + \alpha t)$, gives $(p - p)v = H\alpha(t_1 - t)$. Hence, putting D for the weight of a cubic metre of the gas at 0°, and c for its specific heat when kept at a constant volume, we have for the quantity of heat which must be imparted to the gas to produce the change in question, the expression—

$$q = Dc(t_1 - t);$$

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but, by the last equation, $t_1 - t = v\frac{p' - p}{Ha}$, therefore—

$$q = \frac{D}{Ha} c\, v\, (p' - p) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (g)$$

2. When the gas passes from the condition D to the condition B, it remains under the constant pressure p', but its volume increases from v to v': its temperature must therefore be still further raised to t', which is given by the formula $p'v' = H(1 + at')$. This, combined with $pv = H(1 + at_1)$, gives $p'(v' - v) = Ha(t' - t_1)$; hence the quantity of heat required will be $q_1 = Dc'(t' - t_1)$, c' denoting the specific heat under constant pressure. Putting for $t' - t_1$ its value deduced from the previous equation, this becomes—

$$q_1 = \frac{D}{Ha} c' p' (v' - v) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (h)$$

3. In passing from the condition B to the condition C, the gas is cooled without change of volume; the corresponding temperature t_2 is therefore given by the formula $pv' = H(1 + at_2)$, which, combined with $p'v' = H(1 + at')$, gives $(p' - p)v' = Ha(t' - t_2)$. The heat that must be withdrawn will therefore be $q' = Dc(t' - t_2)$, or, by substitution—

$$q' = \frac{D}{Ha} c\, v' (p' - p) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (i)$$

4. Lastly, when the gas passes from the condition C to its original condition A, it cools under the constant pressure p, and its temperature again becomes t, defined by the formula $pv = H(1 + at)$, which, combined with $pv' = H(1 + at_2)$, gives $p(v' - v) = Ha(t_2 - t)$. The quantity of heat to be withdrawn, to cause the temperature to fall from t_2 to t, will be $q'_1 = Dc'(t_2 - t)$, which, by substitution, becomes—

$$q'_1 = \frac{D}{Ha} c' p (v' - v) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (k)$$

The general result is that, during the passage of the gas from the state A to the state B, a quantity of heat is expended which (by g and h) is represented by—

$$Q = q + q_1 = \frac{D}{Ha} [c\, v\, (p' - p) + c' p' (v' - v)]; \quad . \quad . \quad . \quad . \quad (l)$$

and that, during the return of the gas from the condition B to the condition A, a quantity of heat is evolved, which (by i and k) is expressed by—

$$Q' = q' + q_1' = \frac{D}{Ha} [c\, v' (p' - p) + c' p (v' - v)]. \quad . \quad . \quad . \quad . \quad (m)$$

Consequently, there is an ultimate expenditure of a quantity of heat equal to—

$$Q - Q' = \frac{D}{Ha} (c' - c) (p' - p) (v' - v),$$

a quantity which is necessarily positive, so long as $p' - p$ and $v' - v$ are positive (that is, so long as any actual increase of pressure and volume takes place), being proportional to the product of these two quantities, and represented by the area of the rectangle ADBCA.

By tracing in the same way the heat expended and evolved in the cycle of changes represented by the passage of the point A about the same rectangle, but in the opposite direction, ACBDA, it would be found that, as a final result, a quantity of heat $= Q - Q'$ would be *evolved* by the process instead of expended. Hence we see that the quantity of heat necessary to change the condition of a gas from A $(p\,.\,v)$ to B $(p'\,.\,v')$, depends not only on the nature of the conditions A and B, but also on the manner in which the passage from one to the other takes place.

If B approaches indefinitely near to A, the quantity of heat, $Q - Q'$, expended or evolved as the point A passes round the rectangular circuit approaches indefinitely to the value 0. That is, in order to cause a gas to pass from the condition A to the condition B, infinitely near to it, the same infinitely small quantity of heat must be expended whether the passage is in the direction ADB, the direction ACB, or that of the diameter of the rectangle, AB. Hence, an element, AB, of any curve may be replaced by its two projections DA and DB parallel to the axes, and changes of condition represented by curve-lines may be considered as made up of rectangular elements parallel to these axes, so that the result derived from the consideration of the rectangular circuit ADBCA may be extended to a closed circuit of any form whatever. (Bourget, Ann. Ch. Phys. [3] lvi. 257; also Daguin's *Traité de Physique*, 2nd ed. ii. 512.—See further the section of this article: Relations of Heat to Mechanical Energy.)

Attention must here be drawn to an important consequence of the relations that we

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have found to exist between the pressure, volume, and temperature of a gas. The consequence referred to will be most easily deduced from the above equations (*h*) and (*k*), which show that, when a gas expands from the volume v to the volume v', under the constant pressure p, a quantity of heat is absorbed equal to

$$q = \frac{D}{Ha} c' p (v' - v),$$

and that when the gas contracts from the volume v' to the volume v, under the same pressure, an equal quantity of heat is evolved. It is plain, however, from the above equation, that if p, the pressure upon the gas, is nothing, the quantity of heat, q, needed to cause the gas to expand will also be nothing. This condition is actually fulfilled when, instead of having to force up a piston or overcome the pressure of the atmosphere in its expansion, a gas is allowed to expand into a vacuous space; and it has been experimentally proved by Joule that the expansion of a gas, under these circumstances, is not attended with expenditure or absorption of heat. He immersed two copper vessels in water, and removed the air from one and compressed an additional quantity of air into the other, until the pressure amounted to 22 atmospheres: on opening a communication between the two, air rushed from the latter vessel into the exhausted one until the pressure in both was 11 atmospheres. Nevertheless, the water by which they were surrounded indicated no alteration of temperature.

Absolute Zero of Temperature.—It results from the fundamental formula of gaseous expansion,

$$p v = J (a + t),$$

that, if the temperature, t, of a gas were reduced until it became $= -a = -273$, the gas would cease to have any gaseous elasticity—the product of elastic force into volume would be $= 0$. The temperature $-273°$ C. is therefore called the **absolute zero** of temperature, and temperatures reckoned from it are called **absolute temperatures**. These are obviously obtained in any case by adding 273 to the number of degrees by which a temperature is expressed on the centigrade scale; and by employing them in the expression of the laws regulating the relations between temperature and other properties, the resulting expressions are often much simpler than those required when temperatures are expressed according to any ordinary thermometric scale. Thus, for instance, by using τ $(= t + 273)$ to denote the absolute temperature corresponding to the centigrade temperature t, we have for the fundamental formulæ (a) and (b) (page 45) relating to pressure, volume, and temperature, the expressions

$$p v = J \tau \text{ and } \frac{p' v'}{p v} = \frac{\tau'}{\tau},$$

and corresponding simplifications will be found to result in many other cases.

Expansion of Liquids.—The relation between the volume of a given weight of liquid and its temperature follows no simple general law, such as that which, as we have seen, applies, at least approximately, in the case of gases. On the other hand, not only has almost every liquid a coefficient of expansion different from that of any other, but the coefficient of the same liquid varies to an important extent with changes of temperature.

In consequence of the small extent to which the volume of liquid substances is influenced by external pressure (ELASTICITY, ii. 370), it may, in all ordinary cases, be considered as a function of their temperature alone, instead of as a function of temperature and pressure combined, as with gases. It results also from the cohesion of liquids, which causes them always to have a definite limiting surface, that their volumes can be determined by observations of a more direct kind than those which can be made on gaseous bodies. Hence, an obvious method of determining the expansion of a liquid, is to observe how many divisions of a vessel graduated into parts of equal capacity, are filled by the same weight of it at various temperatures. Such a method, however, would only be exact if the capacity of the containing vessel were known, not merely at some one temperature, but at each temperature at which an observation of the liquid was made. Thus, it would be inaccurate to conclude that the expansion of a liquid between 0° and 100° amounted to 1 per cent., because the same quantity which filled 100 divisions at the former temperature occupied 101 divisions at the latter; for it is impossible to raise the temperature of a liquid, without at the same time raising the temperature, and so altering the capacity, of the vessel in which it is contained. It is therefore necessary to distinguish between the *apparent* expansion of liquids, or that which would result from observations made in the manner that has been described, without taking account of the changes of capacity of the containing vessel, and their *real* or *absolute* expansion, which is the apparent expansion corrected for the simultaneous expansion of the vessel. Of course, in measuring the changes of volume of gaseous bodies, the expansion of the containing vessel requires to be similarly taken

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into account, but in this case it is of much less relative consequence than it is in the case of liquids: thus, for example, the apparent expansion of air in a glass vessel would only differ from its real expansion about in the proportion of 140 : 141; whereas, in the case of mercury, the difference would amount to one seventh of the total effect to be observed.

Relation between the Absolute and Apparent Expansion of Liquids.—From what has been already said, it will be evident that the apparent expansion of a liquid is equal to its absolute expansion for the same interval of temperature diminished by the corresponding expansion of the containing vessel. That is, if Δ be the coefficient of absolute expansion of a liquid, and δ its coefficient of apparent expansion, the relation between these two quantities will be the following:—Let V be the volume of the liquid, and consequently of that portion of the vessel which it fills, at 0°; and let V' be the capacity, *estimated at* 0°, of so much of the vessel as it fills when its temperature has been raised 1°. Then the real volume of the liquid at the latter temperature will be $V(1 + \Delta)$, and the real volume of the portion of the vessel occupied by it will be $V'(1 + \kappa)$ (putting κ for the coefficient of cubical expansion of the material of the vessel): hence we have—

$$V'(1 + \kappa) = V(1 + \Delta),$$

or

$$\frac{V' - V}{V} = \frac{\Delta - \kappa}{1 + \kappa};$$

but $V' - V$ is the apparent increase of volume of the liquid, for a rise of temperature of one degree; $\frac{V' - V}{V}$ is therefore its coefficient of apparent expansion $= \delta$. Accordingly—

$$\delta = \frac{\Delta - \kappa}{1 + \kappa}, \text{ or } \Delta = \delta + \kappa + \delta\kappa;$$

but as δ and κ are always small fractions, we may disregard their product, $\delta\kappa$, and put $\Delta = \delta + \kappa$: that is, the *coefficient of absolute expansion of a liquid is equal to its coefficient of apparent expansion in a vessel of any material, increased by the coefficient of cubical expansion of the material of which the vessel is made.*

By far the most accurate method of measuring the capacity of a vessel, and of finding the relative values of divisions which may be marked upon it, is to determine the weight of mercury which fills it up to the zero point of the scale, and also the weight which corresponds to the interval between any two divisions. But since both the capacity of the vessel and the specific gravity of mercury vary with variations of temperature, the different weights of mercury which fill the vessel at different temperatures do not at once enable its relative capacities at these temperatures to be calculated; for this it is necessary that the absolute expansion of mercury should be previously known. Hence the absolute expansion of mercury (which, on account of its inalterability and its property of not wetting glass, is better adapted for measuring purposes than any other liquid) is a necessary preliminary datum for the determination of the absolute expansion of liquids in general.

Determination of the Absolute Expansion of Mercury.—Enough has already been said to make it evident that, in order to obtain a trustworthy determination of this constant, some method must be devised whose results are wholly unaffected by changes in the capacity of the vessel in which the mercury is contained. A satisfactory solution of this apparently very difficult problem was first given by Dulong and Petit (Ann. Ch. Phys. [2] vii. 124 (1817); Daguin's *Traité de Physique*, 2nd ed. ii. 187; see also Regnault, *Relation des Expériences, &c.*, pp. 277–280. Paris, 1847). Their method consisted in measuring the heights of columns of mercury at different temperatures, which produced equilibrium with another column of the same liquid of constant height, and kept always at 0°.

If h denotes the height of the column at 0°, d the density of mercury at this same temperature, h' the height of the column at t°, which produces equilibrium with the first, and d' the density of mercury at the temperature t, we have—

$$\frac{h'}{h} = \frac{d}{d'}.$$

Representing by v and v' the volumes of the same weight of mercury at 0° and at t°, we get—

$$\frac{d}{d'} = \frac{v'}{v}, \text{ and consequently } \frac{v'}{v} = \frac{h'}{h}.$$

The mean coefficient of expansion between 0° and t° is therefore—

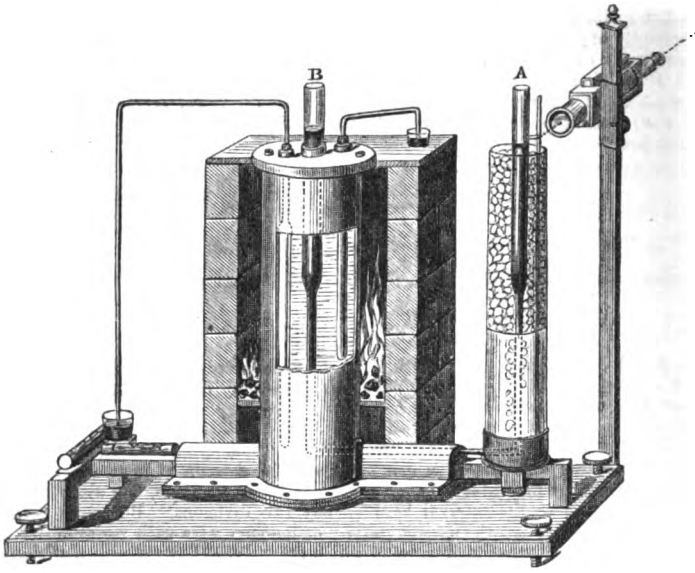
$$\delta_t = \frac{v' - v}{vt} = \frac{h' - h}{ht},$$

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and its determination requires only that the difference of height of the two columns, and the absolute height of the column at zero, should be accurately measured.

The apparatus employed by Dulong and Petit for the purpose of putting this method into practice is represented in *fig.* 534. It consisted of a kind of inverted glass syphon, the two vertical branches of which (A and B) were about 0·55 metre long, and communicated below by a horizontal tube of very small diameter. The branch A was surrounded by a cylinder of tinned iron which was kept full of ice; the other branch, B, occupied the middle of a cylindrical copper vessel filled with oil and built into a furnace.

Fig. 534.



(In the figure, the front wall of the furnace, as well as a part of the cylinders surrounding each branch of the syphon, is represented as having been removed.) The quantity of mercury in the apparatus was so adjusted that the meniscus in the tube B was a little above the cover of the oil-bath, and the difference in the height of the two columns was measured by a cathetometer (an instrument devised by Dulong and Petit and first used in this investigation). The temperature of the oil-bath was indicated by an air-thermometer and a mercurial weight-thermometer (pp. 18, 19), the reservoirs of which were of the same length as the mercury-column in the tube B, and were placed near to and parallel with it.

The following table gives the general results of a great number of determinations made with this apparatus:

Absolute Expansion of Mercury (Dulong and Petit).

Temperatures by the air-thermometer.	Mean coefficient of Expansion counted from 0°.		
	Maximum values.	Minimum values.	Mean values.
100° C. . .	$\frac{1}{5547}$	$\frac{1}{5552}$	$\frac{1}{5550}$ = 0·00018018
200° . . .	$\frac{1}{5419}$	$\frac{1}{5431}$	$\frac{1}{5425}$ = ·00018433
300° . . .	$\frac{1}{5288}$	$\frac{1}{5309}$	$\frac{1}{5300}$ = ·00018868

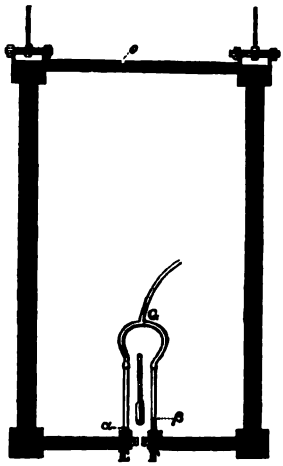
Notwithstanding the great approach to accuracy which was undoubtedly made in these experiments, the results were still affected by sources of error which, in the determination of a physical constant of such primary importance as the one in question cannot be considered as immaterial. The chief of these are: the uncertainty of the determinations of the temperature of the heated column, arising (1) from the employment of the old (and inaccurate) coefficient for the expansion of air, namely 0·0037

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in reducing the indications of the air-thermometer; (2) the cooling effect of the external air upon the portion of the heated column which rose above the cover of the oil-bath; (3) the want of uniformity in the temperature of the oil-bath at different depths; and the comparative shortness of the two mercury-columns, whereby a very small absolute error in the measurement of h and h' comes to have a considerable effect on the value of the fraction $\frac{h' - h}{ht} = \delta$.

In order to obtain results which should be, as far as possible, free from the errors thus arising, Regnault (*Relation des Expériences, &c.*, pp. 271–328. Paris, 1847) repeated the determination of the absolute expansion of mercury, by a method similar in principle to that of Dulong and Petit, but somewhat different in execution. The arrangement of his apparatus will be intelligible from *fig.* 535. AB and CD are two iron tubes, 1·5 metre long and 10 mm. in internal diameter (in the figure the diameter is greatly exaggerated in proportion to the length), connected above by the horizontal iron tube AC, of 2·5 mm. (0·1 inch) internal diameter, and respectively communicating below with the horizontal tubes BE and DF, likewise of 2·5 mm. diameter, which in their turn carry the vertical glass tubes EG and FG. The apparatus having been adjusted so that the tubes AB and CD are exactly vertical, and the tubes AC, BE, and DF exactly horizontal, mercury is poured into it through one of the short tubes, open at both ends, by which both AB and CD are surmounted, and in proportion as the liquid rises in the glass tubes EG and FG, air is compressed into a copper receiver communicating with them by the leaden pipe G, so as to keep the level of the mercury near the bottom of the glass tubes. The addition of mercury is continued until it begins to run out at a hole, O, bored in the upper side of the tube AC. The vertical tube AB is placed in the centre of an oil-bath; CD is surrounded by a constant current of cold water.

Fig. 535.



On heating the tube AB, the density of the mercury contained in it was of course diminished, and consequently equilibrium of pressure in the tubes EG and FG could only be maintained by the sinking of the mercury-column in the former. The elastic force of the compressed air in the receiver was therefore balanced—on the one hand, by the pressure of the heated column of mercury of the height AB, $= H$, diminished by that of the column in E, $= h$; on the other hand, by the pressure of the cold column CD, $= H'$, diminished by that of the column in F, $= h'$. The temperature of the column AB was indicated by an air-thermometer, that of CD by three mercurial thermometers in the water-vessel which surrounded it, and that of the mercury in E and F by a thermometer placed between them as shown in the figure. When the necessary corrections for the differences of temperature of the several mercury-columns had been applied, the formula for the absolute expansion became—

$$\frac{(H' - h') - (H - h)}{(H' - h')t} = \delta.$$

But since the required corrections involved the knowledge of the very coefficient sought, the calculation could only be made by the method of successive approximations: that is, Dulong and Petit's coefficient was first assumed in order to calculate an approximate result; then the number so obtained was substituted for the old coefficient, and so a still more accurate result was arrived at.

In another series of experiments, the tubes AB and CD were connected at the bottom by a continuous horizontal tube, and the tube AC was cut across, vertical glass tubes being inserted into the two halves, wherein the different heights attained by the mercury-columns could be observed. In this state, the apparatus was merely a modified form of that employed by Dulong and Petit.

The results ultimately arrived at are given in the following table, the temperatures in the first column of which are those measured by the air-thermometer.

The numbers in the last column of this table represent the amounts by which a unit volume of mercury expands for a rise of temperature of one degree centigrade at various temperatures between 0° and 350°. Thus, 100,000,000 cubic millimetres of mercury, measured at 0°, occupy 100,017,905 cubic millimetres at 1°; 100,000,000 cubic milli-

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Absolute Expansion of Mercury (Regnault).

Temperature = t.	Volume at $t°$.	Mean coefficient of expansion between 0° and $t°$.	True coefficient of expansion at $t°$.
0°	1·000000	0·00000000	0·00017905
10	1·001792	0·00017925	0·00017950
20	1·003590	0·00017951	0·00018001
30	1·005393	0·00017976	0·00018051
40	1·007201	0·00018002	0·00018102
50	1·009013	0·00018027	0·00018152
60	1·010831	0·00018052	0·00018203
70	1·012655	0·00018078	0·00018253
80	1·014482	0·00018102	0·00018304
90	1·016315	0·00018128	0·00018354
100	1·018153	0·00018153	0·00018405*
110	1·019996	0·00018178	0·00018455
120	1·021844	0·00018203	0·00018505
130	1·023697	0·00018228	0·00018556
140	1·025555	0·00018254	0·00018606
150	1·027419	0·00018279	0·00018657
160	1·029287	0·00018304	0·00018707
170	1·031160	0·00018329	0·00018758
180	1·033039	0·00018355	0·00018808
190	1·034922	0·00018380	0·00018859
200	1·036811	0·00018405	0·00018909
210	1·038704	0·00018430	0·00018959
220	1·040603	0·00018456	0·00019010
230	1·042506	0·00018481	0·00019061
240	1·044415	0·00018506	0·00019111
250	1·046329	0·00018531	0·00019161
260	1·048247	0·00018557	0·00019212
270	1·050171	0·00018582	0·00019262
280	1·052100	0·00018607	0·00019313
290	1·054034	0·00018632	0·00019363
300	1·055973	0·00018658	0·00019413
310	1·057917	0·00018683	0·00019464
320	1·059866	0·00018708	0·00019515
330	1·061820	0·00018733	0·00019565
340	1·063778	0·00018758	0·00019616
350	1·065743	0·00018784	0·00019666

metres, measured at 300°, become 100,019,413 cubic millimetres at 301°. Accordingly, the true coefficient of expansion increases as the temperature rises. The third column contains the quotients obtained by dividing the difference between the volume (V_t) of mercury at $t°$ and the volume of the same weight at 0° ($V_0 = 1$) by the number of degrees of temperature ($= t$), that is to say, the mean coefficient of expansion between 0° and $t°$, $\frac{V_t - 1}{t}$. Between 0° and 100°, the mean coefficients vary so little that the real expansion of mercury, and much more therefore its smaller apparent expansion in glass, may be taken as proportional to the temperature measured by the air-thermometer. A careful comparison of an air-thermometer and a mercurial thermometer, upon which the points 0° and 100° had been determined under the same circumstances, and which therefore necessarily agreed at these temperatures, showed the following differences between the indications of the two instruments:

Temperatures by air-thermometer—

−36° 0° +100° 129·9° 148·7° 197·0° 245° 292·7° 340°;

Temperatures by mercurial thermometer—

−36° 0° +100° 130° 150° 200° 250° 300° 350°.

From Regnault's table it results that, if the real expansion of mercury be taken as the measure of temperature, the following readings of the air- and mercurial thermometers will indicate the same temperatures—

* In Regnault's original paper, the true coefficient of expansion at 100° is given, doubtless in consequence of a misprint, as 0·00018305, and the same number is repeated in various other places: *e.g.* Handwörterb. der Chemie, 2nd ed. ii. [1], 867, article *Ausdehnung*; also Daguin's *Traité de Physique*, ii. 193. Paris, 1861.

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Air-thermometer—

0° 50° 100° 130° 150° 200° 250° 300° 350°;

Mercurial thermometer—

0° 49·6° 100° 130·5° 151° 202·8° 255·2° 308·3° 362·2°.

By a series of observations of the heights of two mercurial barometers, one of which was kept at a temperature near 0° C., while the other was heated to a higher temperature, Militzer (Pogg. Ann. lxxx. 55) obtained for the mean coefficient of absolute expansion of mercury between 0° and 100°, the number

$$0{\cdot}00017405 \pm 0{\cdot}00000082 = \frac{1}{5745{\cdot}4}\left(1 \pm \frac{1}{212}\right),$$

which differs considerably from Regnault's result, and is probably less accurate.

Apparent Expansion of Mercury, and determination of the Cubical Expansion of Glass vessels.—By help of the foregoing table of the absolute expansion of mercury, the cubical expansion of glass vessels may be determined. For this purpose the neck of the vessel is drawn out to a capillary point; it is filled with mercury, care being taken to exclude all moisture or air; exposed successively to the temperatures 0° and 100°, and weighed with the quantity of mercury which fills it at each of these temperatures. Let

the weight of the empty glass vessel be . . . . . = w,
the weight of the vessel filled with mercury at 0° . . . . . = W,
the weight of the vessel filled with mercury at 100° . . . . . = W',

let Δ be the absolute expansion of mercury, and κ the cubical expansion of glass between 0° and 100°; then we have

$$\frac{W - w}{W' - w} = \frac{1 + \Delta}{1 + \kappa}, \text{ and therefore } \kappa = \frac{W' - w}{W - w}(1 + \Delta) - 1.$$

When once the cubical expansion of a glass vessel is known, the absolute expansion of any liquid can be deduced, in the manner already explained (p. 53), from its apparent expansion as observed in this vessel. Hence a problem of frequent occurrence is to determine the expansion of the glass of a vessel shaped like a thermometer, and provided with a divided stem, for which the relative capacities of the bulb and of one division of the stem have been previously determined. In such a case, it is only necessary to fill the apparatus to some particular point of the scale with well-boiled mercury, and to observe the apparent volumes of the mercury, v and v', at 0° and 100°, expressed in divisions of the scale: the expansion of the glass can then be calculated. For (p. 53) the apparent volume of the mercury at 100° is equal to its volume at 0° increased by the amount of its absolute expansion between 0° and 100°; that is:—

$$v'(1 + \kappa) = v(1 + \Delta), \text{ or } \kappa = \frac{v}{v'}(1 + \Delta) - 1.$$

The apparent expansion of mercury in glass varies with the kind of glass employed, but may be taken on an average = 0·0001545 for each degree centigrade. This value may be used, for instance, without hesitation in calculating the corrected length of the portion of the thread of mercury in a thermometer which is not exposed to the temperature that is to be measured. (See below, *Determination of Boiling Points.*) Between 0° and 100° the apparent volume of mercury in glass increases in the proportion of 1 : 1·01545, while the real volume increases in the proportion of 1 : 1·01815; hence the cubical expansion of glass is

$$\kappa = \frac{1{\cdot}01815}{1{\cdot}01545} - 1 = 0{\cdot}002663.$$

Another case in which the absolute expansion of mercury requires to be taken into account, is in reducing barometric observations to 0° C. (Barometer, i. 512, 513.)

Expansion of other Liquids.—The absolute expansion of any liquid can now be ascertained by filling with it a small glass bottle, whose cubical expansion has been previously ascertained in the manner already described, and weighing the bottle with the quantity of liquid which fills it at different temperatures. But a more rapid method, and therefore one more frequently adopted, is to observe the apparent expansion of the liquid in a *dilatometer*, an instrument shaped just like a common mercurial-thermometer, and then to correct these observations for the previously known cubical expansion of the glass. In this way very numerous determinations have been made by Isidore Pierre (Ann. Ch. Phys. [3] xv. 325; xix. 193; xx. 5; xxi. 336; xxxi. 118; xxxiii. 199) and by Hermann Kopp (Pogg. Ann. lxxii. 1 and 223; Ann. Ch. Pharm. xciv. 257; xcv. 307; xcvi. 153 and 303; c. 19). The principal results of these investigations are given below.

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Expansion of Water. (Kopp.)

Temperature.	Volume. (Volume at 0° = 1.)	Density. (Density at 0° = 1.)	Volume. (Volume at 4° = 1.)	Density. (Density at 4° = 1.)
0°	1·00000	1·000000	1·00012	0·999877
1	0·99995	1·000053	1·00007	0·999930
2	0·99991	1·000092	1·00003	0·999969
3	0·99989	1·000115	1·00001	0·999992
4	0·99988	1·000123	1·00000	1·000000
5	0·99988	1·000117	1·00001	0·999994
6	0·99990	1·000097	1·00003	0·999973
7	0·99994	1·000062	1·00006	0·999939
8	0·99999	1·000014	1·00011	0·999890
9	1·00005	0·999952	1·00017	0·999829
10	1·00012	0·999876	1·00025	0·999753
11	1·00021	0·999785	1·00034	0·999664
12	1·00031	0·999686	1·00044	0·999562
13	1·00043	0·999572	1·00055	0·999449
14	1·00056	0·999445	1·00068	0·999322
15	1·00070	0·999306	1·00082	0·999183
16	1·00085	0·999155	1·00097	0·999032
17	1·00101	0·998992	1·00113	0·998869
18	1·00118	0·998817	1·00131	0·998695
19	1·00137	0·998631	1·00149	0·998509
20	1·00157	0·998435	1·00169	0·998312
21	1·00178	0·998228	1·00190	0·998104
22	1·00200	0·998010	1·00212	0·997886
23	1·00223	0·997780	1·00235	0·997657
24	1·00247	0·997541	1·00259	0·997419
25	1·00271	0·997293	1·00284	0·997170
26	1·00296	0·997035	1·00310	0·996912
27	1·00319	0·996767	1·00337	0·996644
28	1·00347	0·996489	1·00365	0·996367
29	1·00376	0·996202	1·00393	0·996082
30	1·00406	0·996008	1·00423	0·995787
35	1·00570			
40	1·00753			
45	1·00954			
50	1·01177			
55	1·01410			
60	1·01659			
65	1·01930			
70	1·02225			
75	1·02541			
80	1·02858			
85	1·03189			
90	1·03540			
95	1·03909			
100	1·04299			

The numbers in the second column of the above table, compared with that representing the volume of the same quantity of water at 0°, give the following four interpolation-formulæ—

Between 0° and 25° C.

$$V = 1 - 0{\cdot}000061045\,t + 0{\cdot}0000077183\,t^2 - 0{\cdot}00000003734\,t^3.$$

Between 25° and 50°.

$$V = 1 - 0{\cdot}000065415\,t + 0{\cdot}0000077585\,t^2 - 0{\cdot}000000035408\,t^3.$$

Between 50° and 75°.

$$V = 1 - 0{\cdot}00005916\,t + 0{\cdot}0000031849\,t^2 + 0{\cdot}0000000072848\,t^3.$$

Between 75° and 100°.

$$V = 1 - 0{\cdot}00008645\,t + 0{\cdot}0000031892\,t^2 + 0{\cdot}0000000024487\,t^3.$$

It will be seen that, between 0° and a temperature of about + 4°, water presents the exceedingly rare phenomenon of a substance which contracts when heated and expands

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hen cooled, so that at about 4° it is more dense than at any other temperature. ccording to the first of the above formulæ, the exact temperature at which water ossesses its maximum density would be 4·08°. The results of other experimenters ıdicate in general very nearly the same temperature for this point. For example, Ilällström fixed it at 4·1°, Despretz at 4°, Playfair and Joule at 3·95°, Hagen at 3·87°, rankenheim at 3·86°, Plücker and Geissler at 3·8° (nearly), C. v. Neumann at 3·68°. lthough the melting point of ice (0° C.) is also the point at which water freezes under rdinary circumstances, it may by special precautions be cooled much lower without ecoming solid (p. 74). It is then found that the expansion which takes place when ater is cooled from 4° to 0°, continues as the temperature sinks below the latter tem- erature. This is shown in the following table by Despretz (Daguin's *Traité de Phy- ique*, ii. 205. Paris, 1861), which gives the volumes and densities of water for each legree from − 9° to + 4°, compared with its volume and density at 4° as unity. The omplete table, which extends from − 9° to 100°, agrees in general very closely with hat already given by Kopp; it is therefore not necessary to reproduce it here entire: he portion given corresponds to the last two columns of Kopp's table.

Expansion of Water between − 9° *and* + 4°. (Despretz.)

Tempera- tures.	Volumes.	Densities.	Tempera- tures.	Volumes.	Densities.
− 9°	1·0016314	0·998371	− 2°	1·0003077	0·999692
− 8	1·0013734	0·998628	− 1	1·0002138	0·999786
− 7	1·0011354	0·998865	0	1·0001269	0·999873
− 6	1·0009184	0·999082	+ 1	1·0000730	0·999927
− 5	1·0006987	0·999202	2	1·0000331	0·999966
− 4	1·0005619	0·999437	3	1·0000083	0·999999
− 3	1·0004222	0·996577	4	1·0000000	1·000000

Frankenheim (Jahresber. üb. Chemie, u. s. w., 1852, 51) calculated from Pierre's observations the following empirical formulæ, to express the volume of water at $t°$, compared with its volume at 0° taken as unity:

Between − 13° and 0°.

$$1 - 0{\cdot}00009417\ t + 0{\cdot}000001449\ t^2 - 0{\cdot}0000005985\ t^3.$$

It is not necessary to give the other six similar formulæ which he calculated for other intervals of temperature up to + 98°, nor to reproduce any part of the table which he calculated by means of them, except the following numbers referring to temperatures below 0°:

Temperatures	− 15°	− 10°	− 5°	0°
Volumes .	1·0037684	1·0016851	1·0005819	1·0000000.

Tables of the expansion of water between 0° and 100° have also been constructed by Hagen (see Jahresber. üb. Chemie, u. s. w., 1856, 50), Kremers (*ibid.* 1861, 62), and others.

Kopp's table further shows that water expands more and more rapidly as the temperature rises. This property likewise is found to remain the same when, by increasing the pressure upon it, water is kept liquid at temperatures above 100°. Thus, for example, by observing under the microscope the apparent expansion of water in thermometer-tubes, Sorby (Phil. Mag. [4] xviii. 81) obtained results from which he calculated the following formula for its expansion between 0° and 200°:

$$V = 0{\cdot}9977 + 0{\cdot}000123\ t + 0{\cdot}00000330\ t^2,$$

which accords closely with the formula which he calculated for the same interval of temperature from Kopp's experiments, namely,

$$V = 0{\cdot}997696 + 0{\cdot}0001101\ t + 0{\cdot}00000343\ t^2.$$

Mendelejeff also (Zeitschr. Chem. Pharm. 1861, 33; Ann. Ch. Pharm. cxix. 1) investigated the expansion of water above 100° with the following results:—

Temperatures.	Densities. (Density of water at 4° = 1.)	Volumes. (Volume of water at 0° = 1.)	Volumes calculated by Kopp's formula.
99·8°	0·95903	1·0426	1·0429
131·0	0·93079	1·0722	1·0716
156·8	0·90770	1·1016	1·1014

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The presence of saline substances in solution in water renders its rate of more uniform, both below and above 100°. [For determinations of the rate sion of aqueous solutions, see Kremers (Pogg. Ann. c. 394; Jahresber. üb u. s. w., 1857 [1] 44: chlorides of potassium, sodium, lithium, and barium.— Pogg. Ann. cv. 360; Jahresber. 1858, 41: chlorides of calcium, cadmium, s zinc, magnesium; bromides of potassium, sodium, lithium, barium, strontium.— Pogg. Ann. cviii. 115; Jahresber. 1859, 48: bromides of strontium, calcium sium, zinc, cadmium; iodides of potassium and sodium; hydrochloric acid.— Pogg. Ann. cxi. 60; Jahresber. 1860, 45: iodides of lithium, barium, stront cium, magnesium, zinc, cadmium.—Further, Pogg. Ann. cxiv. 41; Jahresber. 1 nitrates and sulphates of potassium, sodium, lithium; aqueous nitric and s acids), Gerlach (Jahresber. 1859, 42–48: chlorides of potassium, sodium, ammonium, magnesium, calcium, barium, aluminium; sulphates of potass sodium; carbonates of potassium and sodium; tartaric acid, citric acid, can and Sorby (*loc. cit.*: chlorides of potassium and sodium, sulphate of sodium).

The temperature of maximum density of aqueous solutions is lower than that water. In fact, with solutions of many substances, this temperature lies lower ordinary freezing-point of the solution, and is in general (as well as the freezin lower the larger the proportion of saline matter contained in the solution.

Points of Maximum Density and Congelation of Aqueous Solutions. (Despr

Substances.	Weight of substance in 997·45 parts of water.	Temperature of maximum density.	Freezing-poin solution when
Sea-water . . .	. .	− 3·7°	− 1·88
Chloride of sodium .	12·3	+ 1·2	− 0·8
,, ,, . .	24·9	− 1·7	− 1·4
,, ,, . .	37·0	− 4·75	− 2·1
,, ,, . .	74·1	− 16·0	− 4·3
Chloride of calcium .	6·2	+ 3·2	− 0·2
,, ,, . .	12·3	+ 2·05	− 0·5
,, ,, . .	24·7	+ 0·06	− 1·0
,, ,, . .	37·0	− 2·4	− 3·9
,, ,, . .	74·1	− 10·4	− 5·3
Sulphate of potassium .	6·2	+ 2·9	− 0·1
,, ,, . .	12·3	+ 1·9	− 0·3
,, ,, . .	24·7	− 0·1	− 0·55
,, ,, . .	37·0	− 2·3	− 2·1
,, ,, . .	74·1	− 8·4	− 4·1
Sulphate of sodium .	6·2	+ 2·5	− 0·2
,, ,, . .	12·3	+ 1·15	− 0·4
,, ,, . .	24·7	− 1·5	− 0·7
,, ,, . .	37·0	− 4·3	− 1·3
Carbonate of potassium .	37·0	− 3·95	− 3·2
,, ,, .	74·1	− 12·4	− 2·25
Carbonate of sodium .	37·1	− 7·0	− 2·85
,, ,, .	74·1	− 17·3	− 2·2
Sulphate of copper .	58·0	− 0·6	− 1·3
Potash	37·4	− 5·6	− 2·1
,, ...	74·1	− 15·95	− 4·3
Alcohol . . .	74·1	+ 2·3	− 2·8
Sulphuric acid . .	12·3	+ 0·6	− 0·4
,, ,, . .	24·7	− 1·9	− 1·1
,, ,, . .	37·0	− 5·0	− 1·3

In the tables which follow, Kopp has collected together the results of his own a Pierre's determinations of the expansion of nearly ninety other liquids, chiefly organ In each table, the several substances are arranged in the order of their boiling-poin beginning with the lowest. Except where the contrary is stated, the volume of ea liquid at 0° C. is taken as the unit, with which its volume at higher temperatures compared.

Table A (Ann. Ch. Pharm. c. 21) gives the expansion of seven nitrogenous co pounds from the determinations of Kopp and Pierre.

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Table B (*ibid.* xcvi. 163) gives the expansion of forty-two liquids, containing no other elements than carbon, hydrogen, and oxygen, according to the experiments of H. Kopp:—Table C (*ibid.* xcvi. 304) gives the expansion of thirty-eight compounds containing sulphur, iodine, bromine, and chlorine, according to the experiments of Kopp and Pierre.

TABLE A.

	Kopp.		Pierre.	Kopp.				
° C.	Cyanide of methyl (acetonitrile). C^2H^3N.	Nitrate of ethyl. $C^2H^5NO^3$.	Sulphocyanate of methyl. C^2H^3NS.	Oil of mustard. C^4H^5NS.	Aniline. C^6H^7N.	Cyanide of phenyl (benzonitrile). C^7H^5N.	Nitrobenzene. $C^6H^5NO^2$.	° C.
0	10000	10000	10000	10000	10000	10000	10000	0
10	10122	10117	10098	10107	10083	10093	10084	10
20	10250	10244	10200	10215	10167	10186	10168	20
30	10384	10377	10305	10324	10253	10279	10253	30
40	10523	10517	10416	10434	10342	10373	10340	40
50	10669	10661	10531	10546	10433	10467	10428	50
60	10824	10810	10653	10660	10525	10562	10518	60
70	10988	10962	10781	10777	10619	10659	10609	70
80	11161	11116	10909	10897	10716	10757	10701	80
90		11270	11042	11021	10815	10857	10796	90
100			11178	11148	10915	10961	10892	100
110			11318	11280	11018	11067	10990	110
120			11462	11418	11124	11177	11090	120
130			11609	11561	11231	11289	11192	130
140			11760	11708	11341	11406	11297	140
150				11862	11454	11528	11404	150
160					11569	11652	11512	160
170					11686	11783	11623	170
180					11806	11919	11736	180
190					11928	12061	11853	190
200						12209	11972	200
210							12093	210
220							12218	220

From the inspection of these tables it will be seen that, as a general, though not universal, rule, those substances expand most rapidly at ordinary temperatures whose boiling-points are lowest; that isomeric compounds having the same boiling-point, expand at the same or very nearly the same rate (*e. g.* formate of ethyl and acetate of methyl, $C^3H^6O^2$; propionate of ethyl and butyrate of methyl, $C^5H^{10}O^2$; butyrate of ethyl and valerate of methyl, $C^6H^{12}O^2$); that the rate of expansion of each liquid increases as the temperature rises. This last fact becomes still more apparent on comparing the coefficients of expansion at different temperatures (for a table of the true and mean coefficients of expansion of the liquids examined by Pierre, see Gmelin's *Handbook*, i. 226), and a consequence of it is that, when the volumes of different liquids are compared at the same number of degrees below their several boiling-points, the volume of each liquid at its boiling-point being taken as unity, the alterations corresponding to equal intervals of temperature are found to be often much more uniform than when the comparison is made (as in the tables which follow) for the same absolute temperatures. (Tables of Pierre's results, calculated for equal distances from the boiling-points, are given in Gmelin's *Handbook*, i. 227–230.)

Observations of the expansion of liquids by the methods already described are limited to temperatures below the ordinary boiling-points, but by special methods such observations can be extended to higher temperatures, and it is then found that the increasing rate of expansion continues up to the highest points at which determinations can be made, so that, under such circumstances, liquids may expand as rapidly as

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TABLE B.

° C.	Aldehyde. C_2H_4O.	Ether. $C_4H_{10}O$.	Formate of methyl. $C_2H_4O_2$.	Acetate of methyl. $C_3H_6O_2$.	Formate of ethyl. $C_3H_6O_2$.	Acetone. C_3H_6O.	Methylic alcohol. CH_4O.	Acetate of ethyl. $C_4H_8O_2$.	Alcohol. C_2H_6O.	Benzene. C_6H_6.	Butyrate of methyl. $C_5H_{10}O_2$.	Propionate of ethyl. $C_5H_{10}O_2$.	Formic acid. CH_2O_2.	Water. H_2O.	Valerianic aldehyde. $C_5H_{10}O$.	Butyl. C_8H_{18}.	Butyrate of ethyl. $C_6H_{12}O_2$.	Valerate of methyl. $C_6H_{12}O_2$.	Acetic acid. $C_2H_4O_2$.	Carbonate of ethyl. $C_5H_{10}O_3$.	Acetate of amyl. $C_7H_{14}O_2$.	° C.
0	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	0
10	10162	10162	10143	10132	10137	10138	10114	10130	10105	10119	10122	10130	10100	10001	10123	10121	10119	10114	10106	10118	10115	10
20	10337	10312	10292	10271	10277	10281	10233	10264	10213	10241	10247	10261	10202	10016	10251	10244	10242	10232	10213	10237	10231	20
30		10483	10450	10418	10421	10431	10355	10405	10324	10367	10378	10396	10305	10041	10385	10370	10368	10353	10321	10359	10348	30
40		10667	10620	10572	10573	10588	10482	10552	10440	10496	10514	10533	10411	10075	10523	10499	10498	10479	10432	10482	10467	40
50				10733	10735	10754	10612	10706	10562	10630	10655	10678	10619	10118	10667	10633	10634	10611	10545	10611	10589	50
60				10901	10912	10928	10749	10869	10691	10769	10804	10828	10631	10166	10816	10773	10775	10747	10662	10743	10715	60
70							10891	11040	10828	10914	10969	10984	10746	10223	10969	10919	10922	10888	10782	10880	10846	70
80								11221	10974	11064	11123	11151	10865	10286	11126	11071	11075	11036	10907	11021	10981	80
90										11220	11294	11326	10988	10354	11288	11233	11236	11190	11036	11169	11123	90
100											11475	11510	11115	10430	11452	11404	11405	11350	11172	11322	11271	100
110															11620	11585	11582	11518	11313	11483	11427	110
120																	11768	11692	11461	11651	11592	120
130																				11827	11766	130
140																					11949	140

TABLE B—*continued.*

° C.	Amylic alcohol. $C_5H_{12}O$.	Propionic acid. $C_3H_6O_2$.	Acetic anhydride. $C_4H_6O_3$.	Butyric acid. $C_4H_8O_2$.	Oxalate of methyl. $C_4H_6O_4$.	Cymene. $C_{10}H_{14}$.	Valerianic acid. $C_5H_{10}O_2$.	Bitter-almond oil. C_7H_6O.	Oxalate of ethyl. $C_6H_{10}O_4$.	Valerate of amyl. $C_{10}H_{20}O_2$.	Benzoate of methyl. $C_8H_8O_2$.	Phenol. C_6H_6O.	Benzoate of ethyl. $C_9H_{10}O_2$.	Benzylic alcohol. C_7H_8O.	Succinate of ethyl. $C_{14}H_{14}O_4$.	Naphthalene. $C_{10}H_8$.	Salicylate of methyl. $C_8H_8O_3$.	Cumhol. $C_{10}H_{12}O$.	Benzoic acid. $C_7H_6O_2$.	Cinnamate of ethyl. $C_{11}H_{12}O_2$.	Benzoate of amyl. $C_{12}H_{16}O_2$.	° C.
0	10000	10000	10000	10000	(The volume at the	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	(The volume at the	10000	10000	(The volume at the	10000	10000	0
10	10098	10110	10107	10105		10094	10105	10093	10108	10103	10090	10069	10093	10080	10101		10084	10084		10082	10084	10

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20	10192	10222	10218	10212	melting-point, 30°, taken as unity)	10190	10210	10186	10218	10207	10182	10142	10186	10160	10203	melting-point, 79·4°, taken as unity.)	10170	10169	melting-point, 121·4°, taken as unity.)	10165	10169	20
30	10289	10334	10333	10320		10286	10314	10277	10330	10313	10277	10218	10279	10242	10307		10267	10255		10249	10255	30
40	10388	10448	10451	10431		10385	10420	10368	10444	10420	10374	10298	10374	10325	10412		10345	10343		10335	10343	40
50	10490	10565	10574	10544	10000	10486	10528	10469	10561	10528	10472	10381	10469	10410	10518		10435	10431		10423	10433	50
60	10596	10683	10700	10660	10110	10589	10638	10561	10681	10639	10573	10466	10568	10496	10628		10526	10521		10513	10524	60
70	10708	10805	10830	10779	10222	10694	10749	10646	10805	10752	10677	10554	10666	10585	10740		10619	10612		10604	10617	70
80	10827	10930	10964	10901	10338	10801	10865	10741	10933	10869	10783	10647	10767	10677	10855	10006	10714	10705		10697	10713	80
90	10953	11059	11103	11027	10457	10914	10984	10839	11065	10992	10892	10742	10869	10771	10973	10083	10810	10800		10792	10810	90
100	11088	11192	11245	11157	10578	11028	11106	10939	11200	11117	11005	10841	10975	10866	11094	10163	10909	10898		10889	10910	100
110	11235	11329	11391	11291	10703	11146	11233	11042	11341	11247	11121	10943	11082	10964	11219	10247	11011	10999		10988	11012	110
120	11393	11472	11542	11430	10831	11268	11365	11149	11486	11383	11241	11048	11194	11066	11348	10335	11115	11102		11090	11117	120
130	11563	11620	11697	11574	10963	11394	11502	11260	11636	11524	11363	11157	11309	11170	11481	10426	11221	11209	10070	11194	11224	130
140	11748	11774	11856	11724	11097	11526	11646	11376	11791	11672	11489	11268	11428	11278	11619	10521	11330	11318	10153	11300	11333	140
150				11879	11235	11661	11795	11497	11952	11827	11621	11382	11551	11389	11762	10620	11441	11430	10240	11409	11445	150
160				12040	11376	11802	11953	11624	12119	11987	11755	11499	11678	11503	11911	10722	11557	11546	10329	11520	11560	160
170					11522	11948	12117	11757	12292	12156	11894	11618	11810	11620	12065	10827	11675	11666	10420	11635	11677	170
180						12099	12289	11896	12473	12332	12037	11741	11946	11742	12226	10937	11797	11790	10514	11751	11797	180
190									12659	12517	12184	11867	12088	11868	12392	11050	11923	11918	10610	11871	11919	190
200											12336	11996	12236	11998	12565	11166	12051	12051	10709	11993	12045	200
210													12389	12131	12744	11287	12185	12188	10810	12118	12173	210
220														12268	12931	11411	12322	12329	10913	12246	12305	220
230																	12462	12477	11020	12379	12439	230
240																		12630	11128	12514	12577	240
250																			11239	12652	12719	250
260																			11353	12794	12864	260
270																					13012	270

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TABLE C.

°C.	Bromide of methyl. CH_3Br.	Chloride of ethyl. C_2H_5Cl.	Bromide of ethyl. C_2H_5Br.	Sulphide of carbon. CS_2.	Iodide of methyl. CH_3I.	Chloride of acetyl. C_2H_3OCl.	Chloride of silicon. $SiCl_4$.	Iodide of ethyl. C_2H_5I.	Bromine. Br_2.	Chloride of mono-chlorethyl. C_2H_4ClBr.	Chloroform. $CHCl_3$.	Chloride of dichlor-ethyl. $C_2H_4Cl_2$.	Trichloride of phos-phorus. PCl_3.	Chloride of carbon. CCl_4.	Chloride of ethylene. $C_2H_4Cl_2$.	Sulphide of ethyl. $C_4H_{10}S$.	Chloral. C_2HCl_3O.	Chloride of amyl. $C_5H_{11}Cl$.	Disulphide of methyl. $C_2H_6S_2$.	°C.
	Kopp.	Pierre.				Kopp.	Pierre.										Kopp.	Pierre.		
0	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	0
10	10146	10160	10135	10116	10122	10135	10132	10115	10106	10129	10115	10121	10114	10119	10113	10121	10094	10118	10103	10
20	10300	10327	10275	10235	10249	10278	10271	10232	10216	10260	10239	10249	10231	10241	10229	10247	10187	10237	10210	20
30			10423	10369	10382	10425	10419	10356	10327	10394	10369	10383	10361	10367	10348	10377	10281	10360	10320	30
40			10578	10490	10521	10580	10580	10484	10446	10532	10506	10524	10477	10497	10471	10513	10385	10485	10433	40
50				10628	10567	10742	10753	10614	10569	10675	10649	10670	10609	10631	10599	10653	10492	10615	10550	50
60						10910	10942	10749	10696	10825	10795	10822	10747	10772	10731	10800	10616	10750	10671	60
70								10885	10827	10984	10944	10979	10894	10916	10869	10953	10753	10891	10796	70
80												11143	11060	11074	11015	11113	10911	11039	10926	80
90															11166	11458	11091	11193	11057	90
100																	11298	11357	11194	100
110																		11532	11335	110
120																			11482	120

TABLE C—*continued.*

°C.	Sulphydrate of amyl. $C_5H_{12}S$.	Bromide of amyl. $C_5H_{11}Br$.	Chloride of mono-chlorethylene. $C_2H_2Cl_2$.	Chloride of tin. $SnCl_4$.	Kopp.	Chloride of butylene. $C_4H_8Cl_2$.	Perchlorethylene. C_2Cl_4.	Bromide of ethylene. $C_2H_4Br_2$.	Chloride of dichlor-ethylene. $C_2H_2Cl_4$.	Chloride of arsenic. $AsCl_3$.	Chloride of tantalum. $TlCl_4$.	Iodide of amyl. $C_5H_{11}I$.	Chloride of sulphur. S_2Cl_2.	Sulphide of ethyl. $C_4H_{10}SO_2$.	Chloride of mono-chlorethyl. C_2H_4ClBr.	Bromide of silicon. $SiBr_4$.	Bromide of phospho-rus. PBr_3.	Chloride of benzoyl. C_7H_5OCl.	Chloride of antimony. $SbCl_3$.	Bromide of antimony. $SbBr_3$.	°C.
	Kopp.	Pierre.				Kopp.	Pierre.						Kopp.	Pierre.				Kopp.			
0	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	0
10	10146	10160	10135	10116	10122	10135	10132	10115	10106	10129	10115	10121	10114	10119	10113	10121	10094	10118	10103	10103	10
20	10300	10327	10275	10235	10249	10278	10271	10232	10216	10260	10239	10249	10231	10241	10229	10247	10187	10237	10210	10210	20
30			10423	10369	10382	10425	10419	10356	10327	10394	10369	10383	10361	10367	10348	10377	10281	10360	10320	10320	30
40			10578	10490	10521	10580	10580	10484	10446	10532	10506	10524	10477	10497	10471	10513	10385	10485	10433	10433	40
50				10628	10567	10742	10753	10614	10569	10675	10649	10670	10609	10631	10599	10653	10492	10615	10550	10550	50
60						10910	10942	10749	10696	10825	10795	10822	10747	10772	10731	10800	10616	10750	10671	10671	60
70								10885	10827	10984	10944	10979	10894	10916	10869	10953	10753	10891	10796	10796	70
80												11143	11060	11074	11015	11113	10911	11039	10926	10926	80
90															11166	11458	11091	11193	11057	11057	90
100																	11298	11357	11194	11194	100
110																		11532	11335	11335	110
120																			11482	11482	120

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20	10214	10212	10214	10231	10199	10203	taken as unity.)	10189	10200	10194	10198	10193	10203	10189	10194	10171	10174	melting-point, 73·2°, taken as unity.)	melting-point, 0°, taken as unity.)	20
30	10326	10325	10324	10350	10306	10308	10096	10295	10303	10295	10302	10290	10308	10288	10293	10259	10262			30
40	10442	10441	10437	10473	10419	10416	10195	10404	10408	10399	10408	10388	10416	10391	10393	10347	10353			40
50	10561	10562	10554	10599	10538	10529	10297	10516	10516	10506	10517	10488	10526	10494	10496	10438	10444			50
60	10685	10687	10677	10729	10660	10648	10402	10622	10626	10616	10628	10590	10639	10600	10599	10529	10537			60
70	10813	10816	10805	10864	10788	10773	10510	10734	10739	10729	10744	10694	10754	10706	10705	10623	10632			70
80	10944	10950	10935	11003	10920	10903	10620	10849	10854	10844	10864	10802	10872	10813	10812	10719	10729	10055		80
90	11080	11089	11069	11149	11054	11031	10734	10968	10972	10964	10987	10913	10994	10925	10921	10816	10829	10138	10000	90
100	11220	11233	11208	11300	11194	11160	10850	11090	11094	11086	11112	11028	11118	11040	11031	10916	10930	10223	10059	100
110	11365	11383	11349	11457	11336	11290	10970	11217	11218	11211	11243	11147	11245	11159	11148	11018	11035	10310	10120	110
120	11514	11539	11496	11620	11482	11421	11093	11348	11345	11340	11377	11271	11376	11282	11258	11122	11142	10400	10185	120
130					11631	11552	11223	11483	11475	11472	11516	11402	11510	11410	11373	11227	11252	10491	10252	130
140							11360	11621	11610	11607	11658	11537	11647	11542	11490	11335	11364	10584	10322	140
150											11806	11677	11787	11681	11609	11444	11479	10680	10394	150
160													11930	11826	11730	11555	11598	10777	10469	160
170																11668	11721	10877	10547	170
180																11783	11847	10978	10627	180
190																	11978	11082	10711	190
200																	12112	11187	10797	200
210																		11295	10885	210
220																		11405	10977	220
230																		11517	11071	230
240																			11167	240
250																			11267	250
260																			11369	260
270																			11473	270
280																			11580	280

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Expansion of Liquids under Pressure.

Observer .	Drion.[a]			Andréeff.					Mendeleieff.				Regnault.	
Name of substance . . .	Chloride of ethyl.	Peroxide of nitrogen	Sulphurous anhydride.		Sulphurous anhydride.	Ammonia.	Nitrous oxide.	Carbonic anhydride.	Ether.		Alcohol.		Air.	
Boiling-point	+ 11°	+ 26°	− 8°		−10°	− 34°.	− 87·9°.	− 78·2°.	+34·9°.		+78·4°.			
0° C.	100000	100000	100000	−10° C.	9808	9805		9517	0° C.	10000	0° C.	10000	−10° C.	9634
10	101535	101480	101806	−5	9903	9900	9786	9754	78·2°	11508			0	10000
20	103176	103029	103756	0	10000	10000	10000	10000	99·8	12091	99·9°	11294	+10	10366
30	104933	104673	105865	+5	10099	10105	10211	10270	131·2	13150	130·9	11895	20	10733
									157·0	14235			30	11099
40	106798	106442	108140	10	10200	10215	10453	10585					40	11466
50	108771	108367	110607	15	10303	10330	10766	10969					50	11832
60	110889	110484	113311	20	10408	10450	11202	11457					60	12199
70	113176	112828	116300	25	10516			12095					70	12565
													80	12932
80	115670	115440	119664	30	10625								90	13298
90	118426	118365	123516	35	10738								100	13665
100	121490		127958	40	10853									
110	124927		133235										110	14031
													120	14398
120	128871		139797										130	14764
130	133540		148365										140	15131
													150	15497
													160	15864

[a] The volumes given by Drion are the *apparent* volumes, uncorrected for the expansion of the glass: the corrected, or true, volumes would be a little greater.

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gases, or even more rapidly, for equal increments of temperature. Determinations of the expansion of water above 100°, by Mendelejeff, have already been given (p. 59); the preceding table (p. 66) contains the results of the observations of Drion (Ann. Ch. Phys. [3] lvi. 5), Andréeff (*ibid.* lvi. 317), and Mendelejeff (*loc. cit.*) on some other liquids at temperatures above their usual boiling points. To serve as a standard of comparison, the expansion of air is given in the last column of the table.

Expansion of Solids.—In speaking of the expansion of solid bodies, it is needful to distinguish between *linear* expansion, or the increase in length of a linear unit; *superficial* expansion, or the increase in the area of a unit of surface; and *cubical* expansion, or the increase in bulk of a unit of volume. If a solid body, whose length is A linear units, expands, when heated from 0° C. to 1°, so as to measure $A + a$ at the higher temperature, a portion of its surface containing A^2 superficial units at the lower temperature will become $(A + a)^2$ when expanded, and, at the same time, the volume A^3 will become $(A + a)^3$. We have therefore for the increase in length, or

linear expansion, $A + a - A = a$; for the
superficial expansion, $(A + a)^2 - A^2 = 2Aa + a^2$; for the
cubical expansion, $(A + a)^3 - A^3 = 3A^2a + 3Aa^2 + a^3$.

But since a is always a very small fraction of A, a^2 is also a very small fraction of a; hence the second and third terms of these expressions may be omitted. Accordingly, the expansion of A linear units may be taken as a, the expansion of A^2 superficial units as $2Aa$, and the expansion of A^3 cubical units as $3A^2a$. The *coefficients* of linear, superficial, and cubical expansion, or the expansion of one unit of each kind, will therefore be respectively

$$\frac{a}{A}, \quad \frac{2Aa}{A^2} = 2\,\frac{a}{A}, \quad \text{and} \quad \frac{3A^2a}{A^3} = 3\,\frac{a}{A};$$

that is to say, the coefficient of superficial expansion is *twice* as great, and the coefficient of cubical expansion *three times* as great as the coefficient of linear expansion.

When a hollow vessel is heated, its capacity increases to exactly the same extent as it would do if filled with the substance of which its sides are composed; that is, its expansion is the same as the cubical expansion of a solid mass of the same material and dimensions. If κ be the coefficient of cubical expansion of any kind of glass for a rise of temperature of 1° C., a vessel made of this glass and having the capacity V_0 at 0°, would have at $t°$ the capacity $V_1 = V_0 (1 + \kappa t)$. Similar considerations are applicable in the case of a glass vessel which is divided into parts of equal capacity by a scale etched upon the side, when the space comprised between two consecutive divisions at 0° is taken as the unit of capacity. The apparent volume V_1, read off at $t°$, would then correspond to the real volume $V_0 (1 + \kappa t)$ referred to the unit adopted.

Determinations of Linear Expansion.—The linear expansion has been measured for the greater number of such substances as can be obtained in the form of rods or bars of considerable length. For the purpose of such measurements, one end of the bar is fixed immovably, and its length is measured, by means of micrometric apparatus attached to the other end, at two known temperatures, such as 0° and 100° C., which can be maintained constant sufficiently long to make it certain that they have been attained by the bar throughout its whole mass. The following table of linear expansions between 0° and 100° C. is from Ure's *Dictionary of Chemistry*, ed. 1836, pp. 271, 272.

Linear Expansion of Solids by Heat.

	Dimensions which a bar takes at 100° C. whose length at 0° is 1·000000.		Expansion.
Glass tube	Smeaton	1·00083333	
„	Roy	1·00077615	
„	Delue's mean	1·00082800	$\frac{1}{1178}$
„	Dulong and Petit	1·00086130	$\frac{1}{1148}$
„	Lavoisier and Laplace	1·00081166	$\frac{1}{1233}$
Plate glass	„ „	1·00089089	$\frac{1}{1143}$
„ crown glass	„ „	1·00087572	$\frac{1}{1114}$
„ „	„ „	1·00089760	$\frac{1}{1055}$
„ „	„ „	1·00091751	
„ rod	Roy	1·00080787	
Deal	Roy	as glass	
Platinum	Borda	1·00085655	$\frac{1}{1167}$
„	Dulong and Petit	1·00088420	$\frac{1}{1131}$
„	Troughton	1·00099180	
„ and glass	Berthoud	1·00110000	

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Linear Expansion of Solids by Heat.

Dimensions which a bar takes at 100° C. whose length at 0° is 1·000000.

			Expansion.
Palladium	Wollaston	1·00100000	
Antimony	Smeaton	1·00108300	
Cast-iron prism	Roy	1·00110940	
Cast-iron	Lavoisier, by Dr. Young	1·00111111	
Steel	Troughton	1·00118990	
Steel rod	Roy	1·00114470	
Blistered steel	Phil. Trans. 1795, 428	1·00112500	
„ „	Smeaton	1·00115000	
Steel not tempered	Lavoisier and Laplace	1·00107875	$\frac{1}{537}$
„ „	„ „	1·00107956	$\frac{1}{536}$
„ tempered yellow	„ „	1·00136900	
„ „ „	„ „	1·00138600	
„ „ „ at a higher heat	„ „	1·00123956	$\frac{1}{807}$
Steel	Troughton	1·00118980	
Hard steel	Smeaton	1·00122500	
Annealed steel	Muschenbroek	1·00122000	
Tempered steel	„	1·00137000	
Iron	Borda	1·00115600	
„	Smeaton	1·00125800	
Soft iron, forged	Lavoisier and Laplace	1·00122045	
Round iron, wire drawn	„ „	1·00123504	
Iron wire	Troughton	1·00144010	
Iron	Dulong and Petit	1·00118203	$\frac{1}{845}$
Bismuth	Smeaton	1·00139200	
Annealed gold	Muschenbroek	1·00146000	
Gold	Ellicot, by comparison	1·00150000	
„ procured by parting	Lavoisier and Laplace	1·00146606	$\frac{1}{682}$
„ Paris standard, unannealed	„ „	1·00155155	$\frac{1}{645}$
„ „ „ annealed	„ „	1·00151361	$\frac{1}{661}$
Copper	Muschenbroek	1·00191000	
„	Lavoisier and Laplace	1·00172244	$\frac{1}{581}$
„	„ „	1·00171222	$\frac{1}{584}$
„	Troughton	1·00191880	
„	Dulong and Petit	1·00171821	$\frac{1}{581}$
Brass	Borda	1·00178300	
„	Lavoisier and Laplace	1·00186671	
„	„ „	1·00188971	
Brass scale, supposed from Hamburg	Roy	1·00185540	
Cast Brass	Smeaton	1·00187500	
English plate-brass, in rod	Roy	1·00189280	
„ „ in a trough form	„	1·00189490	
Brass	Troughton	1·00191880	
„ wire	Smeaton	1·00193000	
„	Muschenbroek	1·00216000	
Copper 8, tin 1	Smeaton	1·00181700	
Silver	Herbert	1·00189000	
„	Ellicot, by comparison	1·00210000	
„	Muschenbroek	1·00212000	
„ of cupel	Lavoisier and Laplace	1·00190974	$\frac{1}{524}$
„ Paris standard	„ „	1·00190868	$\frac{1}{524}$
Silver	Troughton	1·00208260	
Brass 16, tin 1	Smeaton	1·00190800	
Speculum metal	„	1·00193300	
Spelter solder; brass 2, zinc 1	„	1·00205800	
Malacca tin	Lavoisier and Laplace	1·00193765	$\frac{1}{514}$
Tin from Falmouth	„ „	1·00217298	$\frac{1}{460}$
Fine pewter	Smeaton	1·00228300	
Grain tin	„	1·00248300	
Tin	Muschenbroek	1·00284000	
Soft solder; lead 2, tin 1	Smeaton	1·00250800	
Zinc 8, tin 1, a little hammered	Smeaton	1·00269200	
Lead	Lavoisier and Laplace	1·00284836	$\frac{1}{3}$
„	Smeaton	1·00286700	
Zinc	„	1·00294200	

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Linear Expansion of Solids by Heat.

Dimensions which a bar takes at 100° C. whose length at 0° is 1·000000.		Expansion.
Zinc, hammered out ½ inch per foot .	Smeaton	1·00301100	
Glass, from 0° to 100° . . .	Dulong and Petit . .	1·00086130	$\frac{1}{1161}$
„ from 100° to 200° . . .	„ „ . .	1·00091827	$\frac{1}{1089}$
„ from 200° to 300° . . .	„ „ . .	1·000101114	$\frac{1}{987}$

The last two measurements by an air-thermometer.

Messrs. Calvert, Johnson, and Lowe have determined the linear expansion of a considerable number of metals and alloys by a modification of the method above described, for the details of which we must refer to the original paper published in the *Mechanics' Magazine*.

The following are the linear expansions of simple metals between 0° and 100° C. thus determined:—

Cadmium (pure)	0·00332
Lead (pure)	0·00301
Tin (pure)	0·00273
Aluminium (commercial)	0·00222
Zinc, forged (pure)	0·00220
Silver (pure)	0·00199
Gold (pure)	0·00138
Bismuth (pure)	0·00133
Wrought iron	0·00119
Cast iron	0·00112
Steel (soft)	0·00103
Antimony (pure)	0·00098
Platinum (commercial)	0 00068

From the preceding table it will be seen that the coefficients of expansion of the metals vary with their physical condition, being different for the same metal according as it has been cast, hammered and rolled, hardened, or annealed. As a general rule, those operations which increase the density, appear also to increase the rate of expansion by heat. But even for substances in apparently the same condition, different observers have found very unequal amounts of expansion; this may arise, in the case of compound substances, such as glass, brass, or steel, from a want of uniformity in chemical composition, and in simple bodies from slight differences of physical state. Hence, in all cases where great accuracy is required in the determination of the linear expansion, as in rods employed for pendulum observations, or for the measurement of the base-lines of surveys, it is impossible to rely upon the results of previous determinations of the expansion of the material in question; but the linear expansion of each individual rod must be determined by a special experiment: this was done, for instance, by De Borda, with each of the four platinum measuring rods (each two toises, or twelve French feet long), which were employed in the measurement of the arc of meridian, from which the length of the metre was deduced.

Copper rods were laid upon the platinum rods, and both were firmly fixed together at one end; the copper rods carried a divided scale at the other end, which indicated directly the twenty-thousandth part of their length, while by means of a vernier attached to the corresponding end of the platinum rods, tenths of these divisions, or about the one-hundredth part of a French line, could be read off. In this way, the difference in the expansion of two rods of the same length but different materials can be determined with great accuracy, and if the coefficient of expansion for the material of one rod is known, the coefficient of that of the other can be calculated.

If both rods have the same length, L, at 0°, and at $t°$ one has the length $L' = L(1 + \alpha t)$, the other the length $L'' = L(1 + \alpha' t)$, we have $L' - L'' = L t(\alpha - \alpha')$. But $L' - L''$ is the observed difference of length at the temperature $t°$; and hence if α is known, α' is easily calculated. In this way, Dulong and Petit deduced the linear expansion of copper from that of platinum.

If, on the other hand, the expansion of the material of two rods thus united is known, and can be taken as proportional, within certain limits of temperature, to the indications of the mercurial thermometer, the combination of the two rods may be employed as a metallic thermometer. The measurement of temperatures in this way is specially valuable in the case of standard measures of length, which can thus be made to indicate their own temperature. If, for instance, the two rods have the same length at 0°, and differ at 100° by the amount D, and at $t°$ by the amount d, the temperature is given by the equation $t = \frac{d}{D}\,100$.

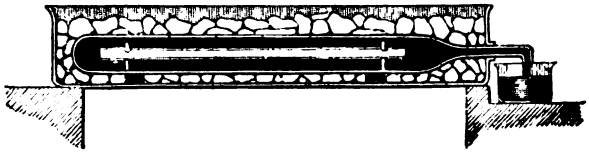
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The unequal expansion of different metals has been taken advantage of for the co struction of thermometers of another kind. If two straight strips of different meta are fastened together throughout their whole length, any variation of temperature mu cause the compound strip to bend, so that the least expanded metal will be on the co cave side, and the most expanded metal on the convex side of the curve. Breguet' thermometer, constructed upon this principle, is made from a compound plate of platinum gold, and silver, soldered together, the gold in the middle. This is rolled out very thi and cut into very narrow strips, which are coiled round into spirals. The thermomete consists of such a spiral suspended by one end from a support, and carrying a needl which swings round a divided circle at the other.

Supposing the silver to be inside of the spiral, any rise of temperature will be ind cated by the untwisting of the spiral, and a fall of temperature by its twisting mo tightly. The small mass of this instrument, and the low specific heat of the materia composing it, cause it to indicate changes of temperature very rapidly, and to be affecte by very small quantities of heat.

Determinations of Cubical Expansion.—When the coefficient of linear expansion a substance is known, its coefficient of cubical expansion is obtained by multiplyin the linear coefficient by 3, as already explained (p. 67). The cubical expansion ca also be ascertained by direct measurement. The following method was employe by Dulong and Petit for this purpose: Into a glass tube, 18 millimetres wide, decimetres long, and closed at one end, they introduced a rod, previously weighed. a metal not attacked by mercury. Let W be its weight. The tube was then draw out at the open end and bent as in *fig.* 536, after which it was filled with pure me cury, and boil out to remo every trace of a exactly as in filli a mercurial the mometer. In t state the appar tus was placed h rizontally, a surrounded wi

Fig. 536.



melting ice, the point dipping below the surface of mercury contained in a sm capsule. It was thus filled with mercury at 0°. The capsule was next emptie replaced under the point, and the apparatus allowed again to assume the temperatu of the atmosphere. Then, by weighing together the tube and capsule, and deducti from the gross weight their weight before the introduction of the mercury, they o tained the weight, W, of the mercury which exactly filled at 0° so much of the capaci of the tube as was not occupied by the metal rod. The experiment was completed heating the instrument in an oil-bath to a high temperature, t, and weighing t quantity of mercury which escaped from the point, as in the determination of a te perature by means of the weight-thermometer (p. 18).

If D_0 and D_0' represent the densities at 0° of mercury and of the metal; Δ, $\varkappa$, and the coefficients of cubical expansion of mercury, of the metal, and of glass respectivel their volumes at 0° will be represented by

$$\frac{W}{D_0}, \quad \frac{W'}{D_0}, \quad \text{and} \quad \left(\frac{W}{D_0} + \frac{W'}{D_0'}\right);$$

and if w is the weight of mercury which escapes from the tube between 0° and $t°$, t weight of mercury remaining in the tube at the latter temperature will be $W-$ Then putting the volume of this weight of mercury at the temperature t, together wi that of the metal rod at the same temperature, equal to the capacity of the tube whi contains them, we have

$$\frac{W-w}{D_0}(1+\Delta t) + \frac{W'}{D_0'}(1+\varkappa t) = \left(\frac{W}{D_0} + \frac{W'}{D_0'}\right)(1+\kappa t);$$

whence

$$\varkappa = \frac{D_0'}{W'}\left(\frac{w(1+\Delta t) - W(\Delta t - \kappa t)}{D_0} + \kappa t\right)$$

It is of course necessary that the values of Δ and κ should have been determined previous experiments in the way already described.

Another, to some extent similar, method of measuring the cubical expansion of sol bodies, consists in determining their specific gravities at various temperatures, the bu of a given weight of a substance being inversely as its density.

In applying this method, the weight of water free from air which fills a specif gravity bottle at various temperatures is first ascertained; then, the weight of t bottle is determined at the same temperatures after a known weight of the substar

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under examination has been put into it, and the interstices filled with water. Let W be the weight of water which fills the bottle at the temperature t, W' the weight of the solid substance, and S the weight of water and solid substance which together fill the bottle at $t°$; then the density of the substance at $t°$, compared with that of water at the same temperature, is $D_t = \frac{W'}{W-(S-W')}$; and if V_t represents the bulk which a unit-volume of water measured at 0° assumes at $t°$, the density of the substance at $t°$, compared with that of water at 0°, is $\frac{D_t}{V_t} = D_0$. Lastly, if the density D_0' of the substance at some other temperature $t'°$, has been determined in the same way, its mean coefficient of cubical expansion for one degree between t' and $t°$ is $\frac{D_0 - D_0'}{(t'-t)D_0}$.

Table of Coefficients of Cubical Expansion of Solids for 1° C.

Substance.	Coefficient.	Interval of Temperature.	Observer.
Glass	$\frac{1}{38700}$ = 0·0000258	0° to 100°	Dulong
„	$\frac{1}{363000}$ = ·0000275	0 „ 200	„
„	$\frac{1}{328000}$ = ·0000304	0 „ 300	„
Soft French glass	·0000260	17 „ 99	Kopp
„ „ another kind	·0000253	7 „ 99	„
Hard potash glass	·0000209	16 „ 100	„
Common glass	$\frac{1}{362350}$ = ·0000276	0 „ 100	Regnault
„	$\frac{1}{327250}$ = ·0000305	0 „ 300	„
Crystal glass from Choisy-le-Roi	$\frac{1}{435660}$ = ·0000228	0 „ 100	„
„ „	$\frac{1}{429516}$ = ·0000233	0 „ 300	„
Iron	$\frac{1}{283000}$ = ·0000355	0 „ 100	Dulong
„	$\frac{1}{227000}$ = ·0000441	0 „ 300	„
„ (soft wire)	·0000370	13 „ 100	Kopp
Copper	$\frac{1}{284000}$ = ·0000515	0 „ 100	Dulong
„	$\frac{1}{177000}$ = ·0000565	0 „ 300	„
„ (wire)	·0000518	11 „ 99	Kopp
Platinum	$\frac{1}{377000}$ = ·0000265	0 „ 100	Dulong
„	$\frac{1}{363000}$ = ·0000275	0 „ 300	„
Lead	·0000889	11 „ 100	Kopp
Tin	·0000689	12 „ 99	„
Zinc	·0000893	11 „ 44	„
Cadmium	·0000936	12 „ 43	„
Bismuth	·0000400	12 „ 41	„
Antimony	·0000331	12 „ 43	„
Sulphur	·0001826	14 „ 46	„
Lead-glance	·0000680	14 „ 48	„
Zinc-blende	·0000358	15 „ 45	„
Iron-pyrites	·0000338	15 „ 47	„
Rutile	·0000322	14 „ 46	„
Tin-stone (SnO^2)	·0000163	16 „ 46	„
Specular iron	·0000404	13 „ 47	„
Magnetic iron ore	·0000291	17 „ 50	„
Fluor-spar	·0000623	14 „ 47	„
Arragonite	·0000647	10 „ 43	„
Calc-spar	·0000175	9 „ 42	„
Bitter-spar	·0000352	13 „ 43	„
Spathic iron-ore	·0000350	14 „ 45	„
Heavy spar	·0000581	12 „ 42	„
Cœlestine	·0000608	12 „ 45	„
Orthoclase	·0000225	13 „ 99	„
Quartz	·0000403	18 „ 100	„
Bayeux porcelain	·0000108	0 „ 860	Deville and Troost
„ „	·0000108	0 „ 1000	„

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The cubical expansion of a considerable number of crystallised compounds has al
been determined by Joule and Playfair (Chem. Soc. Qu. J. i. 121; for a tab
of the results, see also Gmelin's *Handbook*, i. 234).

From the determinations given at the beginning of this table, it will be seen th
the coefficients of expansion of solid bodies become greater as the temperature rise
but that the coefficient of expansion of platinum, which at the temperatures of t
experiments is very far from the point at which fusion or softening occurs, increas
much less than the coefficients of expansion of the more fusible metals, copper and iro
The rule thus indicated has been found to be verified in other cases also, so that wi
solids, as well as with liquids, the coefficients of expansion remain sensibly constant
temperatures far removed from those at which change of state occurs, and vary more a
more rapidly as these latter temperatures are approached.

The expansion of amorphous solids, and of those which crystallise in the regul
system (CRYSTALLOGRAPHY, ii. 121), is the same for all dimensions, unless when th
are subject to a mechanical strain in some particular direction. A fragment of such
substance varies in bulk with variations of temperature, but retains always the sam
shape.

Crystals not belonging to the regular system exhibit when heated an unequal e
pansion in the direction of their axes, in consequence of which the magnitude of the
angles becomes altered (Mitscherlich, Pogg. Ann. i. 125; x. 137). In crystals b
longing to the trimetric system, the expansion is different in the direction of all thr
axes; in arragonite, on raising the temperature from 0° to 100°, the inclination of t
lateral faces increases by 2′ 46″, and that of the terminal faces diminishes by 5′ 29
gypsum is, according to Fresnel (Bull. des Sc. Mathem. 1824, 100; also Pogg. An
ii. 109), more expanded by heat in the direction of the principal axis than in that
the lateral axes. In crystals belonging to the hexagonal system, the expansion is t
same in the directions of the three secondary axes; but different from that accordi
to the principal axis. The obtuse angles of the primitive rhombohedron of calcsp
diminish by 8½′ when the crystal is heated 100°, and the acute angles increase by t
same quantity. Hence it may be calculated that the relative expansion of the princip
axis (compared with that of the secondary axes) amounts to 0·00342; moreover sinc
according to Mitscherlich and Dulong, the cubical expansion of calcspar between 0° a
100° is only 0·001961, it may likewise be determined that calcspar, when thus heate
does not expand in the direction of the secondary axes, but *contracts* by 0·00056, a
that the absolute expansion of the principal axis may be estimated at 0·00286. In bitte
spar, the obtuse angle of the primitive rhombohedron diminishes when the temperatu
is raised from 0° to 100° by 4′ 6″, in ferruginous bitter-spar by 3′ 29″; in iron-sp
containing a considerable quantity of manganese, by 3′ 31″, and in pure iron-spar
2′ 22″. Since now, among all these minerals, calcspar forms the least, and ferrugino
bitter-spar the most obtuse rhombohedron, it follows that the expansion in the dire
tion of the principal axis does not increase in the same proportion as the relati
length of the axis itself diminishes (Mitscherlich).

The following direct determinations of the linear expansion of several crystallis
substances, between 0° and 100°, made by Pfaff (Jahresber. 1858, 7), show ve
distinctly the inequality in the amounts of expansion in the direction of the differe
axes.

Linear Expansion of Crystals between 0° and 100°

Monometric Crystals.		Dimetric or Hexagonal Crystals.		
Substance.	Expansion.	Substance.	Expansion.	
			Principal Axis.	Secondary Axes.
Garnet . .	0·0008478	Tin-stone .	0·0004860	0·0004526
Iron-pyrites .	·0010084	Vesuvian .	·0007872	·0009629
Magnetic iron	·0009540	Zircon . .	·0006264	·0011054
Lead-glance .	·0018594	Beryl . .	·0001721	−0·0000132
Fluor-spar .	·0019504	Corundum .	·0006876	·0006551
		Quartz . .	·0008073	·0015147
		Tourmaline .	·0009369	·0007732
		Calc-spar .	·0026261	−0·0003105

NOTE.—A minus sign (−) in the last column denotes contraction, instead of expansion.

This alteration of shape caused by change of temperature is most easily render
evident in gypsum, of which substance twin-crystals often occur, having pretty near

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the form shown in *fig.* 537. From such a crystal, a portion *a b*, *c d* is cut, so that the new surfaces are perpendicular to the surface of combination, *m n*, of the two halves of the crystal, and the face *a b* is ground and polished. At the temperature of the atmo-

Fig. 537.

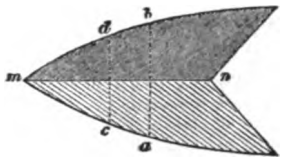
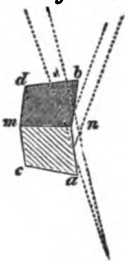


Fig. 538.



sphere, this surface then constitutes a single, unbroken plane; but when it is heated to about 60° or 80° C., the shape of the crystal alters in the manner shown in *fig.* 538, and now parallel rays of light falling on the two halves from a distant object are reflected in different directions, so that two distinct images of the object may be seen simultaneously by reflection from the surface *a b*.

One or two solid bodies are known which, at least within certain limits of temperature, form exceptions to the general rule of expansion by heat, and contract as their temperature is raised. For example, the alloy of 2 pts. bismuth, 1 pt. tin, and 1 pt. lead, expands when heated from 0° to 44° C.; when still further heated, it contracts, so that at 56° its density is the same as it was at 0°, and at 69° still greater; beyond this temperature, expansion again takes place; at 87·5° the alloy has once more the same density as at 0°, and at 94°, at which it fuses, the same as at 44°. (Erman, Pogg. Ann. ix. 557. For the not quite concordant results of H. Kopp, see below, p. 78.)

Again, a piece of vulcanised caoutchouc, which is stretched by a weight to double its length, is shortened by a tenth when its temperature is raised 50° C., and the shortening effect increases rapidly with the stretching weight employed. (Joule, Proc. Roy. Soc. viii. 356.)

Relation between the Specific Heats of Liquid and Solid Bodies, and their Coefficients of Expansion at different temperatures.—It has been pointed out above (p. 40), that the specific heat of any substance includes, not only the portion of heat required to cause in it a given alteration of temperature, but also the quantity of heat which is expended in modifying its condition of molecular equilibrium, and whose most obvious external effect is an alteration of the volume of the substance. We have also seen (p. 44), that although no certain data exist for calculating the ratio of these two parts of the total specific heat, except in the case of gases, it is nevertheless probable that the former part, or the *real specific heat* of a substance, remains the same for all conditions. Hence variations in the total or *apparent specific heat* must be supposed to result from variations in the amount of heat expended in overcoming the molecular forces. In sensibly perfect gases, the consumption of heat in this manner is the same at all temperatures, and so small as to be negligible; accordingly, both the real and apparent specific heats of gases are constant at all temperatures (pp. 34 and 42). On the other hand, the molecular changes which accompany alterations of temperature in liquid and solid bodies are such as require the expenditure of very considerable quantities of heat to produce them. These changes doubtless consist in alterations of the relative position or arrangement of the molecules, but of what precise kind we have no means of ascertaining, since the only measurable portion of the total effect is the externally visible change of volume.

This change of volume cannot be taken as in every case a measure of the amount of molecular work performed by the heat independently of causing alteration of temperature; for, as we have seen (p. 59), the communication of heat to water below 4° C. causes a change of bulk of the opposite kind to that which it occasions above that temperature; but we may nevertheless probably admit without great error that, as a general rule, the proportion of the total quantity of heat required to raise the temperature of a given substance 1°, which is consumed in producing molecular changes, is greatest at those points of the thermometric scale at which the greatest amount of expansion accompanies a rise of temperature of 1°, and is least at those points at which the corresponding expansion is least. If this supposition be admitted, it accounts satisfactorily for the fact that both the specific heats of solid and liquid bodies and their coefficients of expansion increase, as a rule, with rise of temperature; and that both

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these properties vary most rapidly in the neighbourhood of those temperatures which changes of the state of aggregation occur (Comp. Verdet, *Exposé de la Thé Mécanique de la Chaleur*, Paris, 1863, note G, pp. 133 *et seq.*; also Regnault, M Acad. Sciences, xxvi. 285 *et seq.*) On the relations between changes of volume produ by external forces and the corresponding evolution or disappearance of heat, see bel Relations of Heat to Mechanical Energy.

3. *Changes of State of Aggregation produced by Heat.*

Fusion and Solidification.—When the temperature of a solid body is rai continuously, a point is reached sooner or later at which it melts, or exchan the solid for the liquid form; and when a liquid is cooled, a point is in like man attained at which it solidifies. With most homogeneous substances, the passage fr the one state to the other takes place suddenly at some particular temperature; t ice, when heated from a lower temperature to 0° C., becomes only very slightly so or less solid, while if more heat still is imparted to it, it changes at once into perfe liquid water. This temperature forms a definite limit below which we have solid and above which we have liquid water, and it is therefore called the *melting poin* ice. Some substances, however, pass when heated from the solid to the liquid st without showing any definite melting point; for example, glass and iron bec gradually softer and softer when heated, and pass by imperceptible stages from solid to the liquid condition. Such substances may be said to begin to melt at lowest temperature at which perceptible softening occurs, and to be fully melted wl further elevation of temperature does not make them sensibly more fluid; but no p cise temperatures can be given as their melting points.

Subject to the qualifications hereafter stated, the following general laws may taken as applicable to the phenomena of fusion and solidification:—

1°. The state of aggregation of every substance is always the same at the sa temperature: when its temperature is raised, it melts at a certain fixed point, or pa from the solid to the liquid state, and when its temperature is lowered, it solidifies, passes from the liquid to the solid state, at a point which is also fixed, and is the sa as its melting-point. (For substances which melt gradually, a certain fixed inter must be substituted for a fixed point of temperature in the enunciation of this rule.)

2°. The communication of heat to a solid body at its melting point causes it to m but does not raise its temperature; so also the withdrawal of heat from a liquid at freezing point causes it to solidify, but does not lower its temperature.

3°. As a general rule, a sudden change of volume (usually an increase) accompan the passage from the solid to the liquid state.

We will proceed to consider each of these laws and the exceptions and modificati to which they are subject.

Melting and Freezing Points.—Though the temperature at which the pass from the solid to the liquid state takes place, and *vice versâ*, is constant (under same circumstances) for each substance, the melting and freezing points of differ substances vary within very wide limits. Thus sulphurous anhydride melts at − 8 (Mitchell, *Berzel. Jahresber.* xxii. 59), mercury at − 40°, bromine at − 7·3°, ice at phosphorus at + 44°, tin at 235°, silver at 1000°, platinum at 2000° (Deville a Debray). (For the melting points of particular substances, see the articles in t Dictionary where they are respectively described.)

These differences are sufficient to justify the conclusion that even those substan which have never been seen to melt, would do so at a sufficiently high temperature, a conversely that all liquids, even such as have never yet been frozen, would solidify exposed to a still more intense degree of cold. Indeed, in proportion as new methods producing extreme temperatures have been discovered, the number of infusible sol and non-solidifiable liquids has gone on diminishing continually. The only substan which can be considered really infusible are those which, when heated, undergo chemi alteration before their melting point is reached. The most infusible of all substan which are chemically inalterable by heat is, probably, carbon in the form of graphi and even this body was found by Despretz to soften when exposed to the heat produc by the electric current generated by 600 Bunsen's cells arranged in six series of 1 On the other hand, absolute alcohol, sulphide of carbon, and some other liquids ha never been solidified, but at the temperature produced by a mixture of liquid nitr oxide, solid carbonic anhydride, and ether, Despretz found that absolute alcohol beca so viscid that it did not run out on inverting the vessel that contained it.

In very many cases, it happens that a mixture of two or more substances melts a lower temperature than either of its components taken separately: thus, a mixture 1 part chloride of sodium with 2½ or 2¾ parts ice, melts at about − 20°; mixtures fatty acids melt at lower temperatures than the pure acids; the carbonates of potassi

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and sodium melt more easily when mixed than either salt does alone; Rose's fusible alloy of 2 parts bismuth, 1 part tin, and 1 part lead, melts between 95° and 98°; an alloy of 1 or 2 parts cadmium with 2 parts tin, 4 parts lead, and 7 or 8 parts bismuth, melts between 66° and 71° (B. Wood); &c.

In homologous series of analogous organic compounds, the melting point of each term usually rises with its atomic weight.

Under particular circumstances liquids may be cooled below the melting point of the corresponding solid body, without solidifying. This occurs especially when they are cooled very slowly, and are at the same time protected from all mechanical disturbance. For instance water at perfect rest, and under a pressure somewhat greater than that of the atmosphere, may be cooled to −15° without freezing, but contact with a solid body or the slightest agitation is then usually sufficient to cause solidification to commence. The smaller the quantity of liquid operated upon, the lower is the temperature to which it can be cooled, and the greater the mechanical disturbance which it will support without freezing. Thus, Fournet (Ann. Ch. Phys. [3] xlvi. 203) has remarked the frequent occurrence of mists formed by particles of liquid water suspended in an atmosphere of which the temperature was 10, 12, or even 15 degrees below zero; and Sorby found that in glass tubes of 0·1 millimetre in diameter, water could be maintained in the liquid state as low as −17°.

Some remarkable phenomena of this kind have been also observed by Dufour (Ann. Ch. Phys. [3] lxviii. 370) in the case of liquids cooled without contact with any solid body. His method of experimenting was to suspend globules of the liquid under examination in some other liquid of the same specific gravity, but of lower freezing point, and in which it was insoluble. Water was examined while suspended in a mixture of chloroform and sweet oil of almonds; sulphur and phosphorus, in an aqueous solution of chloride of zinc; and naphthalene, in water. In the experiments with water, the spheres of this liquid which floated in the mixture of chloroform and oil were very rarely seen to freeze at 0°; in general, solidification occurred between −4° and −12°, the smallest globules, as a rule, remaining liquid to a lower temperature than the larger ones, some of them having been repeatedly seen still liquid at −18° or −20°. Agitation and the contact of solid bodies appears to have much less effect in causing the solidification of liquids cooled in this way than when they are cooled to the same extent in glass vessels. For instance, Dufour found that the globules of water in his experiments often did not solidify when displaced or violently deformed by a glass rod, and even that crystals of chloride of sodium, sulphate or nitrate of potassium, sugar, &c., would sometimes fall *through* a globule of water 5 millimetres in diameter, and cooled to at least −8°, without producing any effect. Contact with a fragment of ice, however, invariably caused immediate congelation.

By operating as above described, Dufour obtained globules of sulphur (melting point 115°) of 6 millimetres diameter still liquid at 40°, and globules of 0·5 millimetre diameter remained liquid for several days at 5° or 10°. Globules of phosphorus of considerable size were cooled to 20°, and globules of 1 or 2 millimetres diameter to 0° without solidifying. Globules of naphthalene (melting point 79°) were obtained still liquid at 40°.

When a liquid solidifies after having been thus cooled below its normal freezing point, the solidification takes place very rapidly, and is accompanied by a disengagement of heat often sufficient to raise its temperature from the point at which solidification begins up to its ordinary freezing point. This is well seen with crystallised hyposulphite of sodium ($S^2Na^2O^3$, $5H^2O$), which melts in its water of crystallisation at 45°, but when carefully cooled will remain liquid for a long time at the temperature of the atmosphere. If it be then caused to solidify, by agitation, or by throwing in a small fragment of the solid salt, the resulting rise of temperature is such as to be distinctly felt by the hand.

This phenomenon of continued liquidity, though seldom observed in so marked a degree as in the cases above mentioned, occurs so frequently to a less extent, that, when the temperature of transition from the solid to the liquid state or *vice versâ* is to be used as a mark of the chemical identity of a substance, it is much safer to determine the melting point than the freezing point, for the former temperature is not subject to variations of the same kind.

The following method is convenient for taking the melting points of substances in chemical investigations. Three or four glass tubes are drawn out till their sides become very thin and their bore nearly capillary, and into each is introduced a small quantity of the substance to be examined. They are then sealed at the bottom and placed in a beaker-glass containing water (or, if the substance melts above 100°, paraffin or sulphuric acid), and standing upon a small sand-bath by means of which its temperature can be slowly raised. The liquid is heated until the substance melts; then allowed to cool slowly to the point of solidification; it is then again warmed, and

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these operations are repeated, the temperatures of liquefaction and solidification being noted each time, until several closely concordant observations of each have been obtained, the means of which are the melting and solidifying points required.

Influence of Pressure upon Melting Points.—The variations which occur in the pressure of the atmosphere are without perceptible effect in altering the melting points of solids or freezing points of liquids, but greater differences of pressure are found to produce a very sensible effect. This was first observed by Prof. W. Thomson, who found that pressures of 8·1 and 16·8 atmospheres caused a lowering of the melting point of ice to the extent of 0·059° and 0·129° respectively. These results, therefore, verified the previous theoretical conclusions of Prof. J. Thomson, according to which an increase of pressure amounting to n atmospheres must lower the melting-point of ice by $t° = n \cdot 0{\cdot}0075°$,—a formula which gives 0·061° and 0·126° as the differences of melting point corresponding to 8·1 and 16·8 atmospheres pressure. By a still greater pressure, Mousson (Ann. Ch. Phys. [3] lvi. 252) succeeded in maintaining water in the liquid state at 5 degrees below zero, and by a pressure estimated at 13,000 atmospheres he caused ice to melt at —18°. Analogous effects have been observed with other substances by Bunsen (Jahresber. über Chemie, u. s. w., 1850, 48) and Hopkins (*ibid.* 1854, 48). Their results are given in the following table. Bunsen considers that the observations of temperature in his experiments were correct within 0·1°, but that there may be an error of one or two atmospheres in the estimation of the pressures.

Freezing and Melting Points under increased Pressure.

Observer.	Hopkins.				Bunsen.			
Name of Substance.	Spermaceti.	Wax.	Sulphur.	Stearin.	Spermaceti.		Paraffin.	
Pressure in Atmospheres.	Melting point.				Pressure in Atmospheres.	Freezing point.	Pressure in Atmospheres.	Freezing point.
1	51·1°	64·7°	107·2°	67·2°	1	47·7°	1	46·3°
520	60·0	74·7	135·2	68·3	29	48·3	85	48·9
793	80·2	80·2	140·5	73·8	96	49·7	100	49·9
					141	50·5		
					156	50·9		

Latent Heat of Fluidity.—It has been pointed out already (p. 73) that the specific heats of solid bodies increase as they approach their melting points, and this fact has been connected with the increase of the coefficient of expansion which generally occurs simultaneously. In order to raise the temperature of a solid body 1 degree in the neighbourhood of its melting point, more heat is needed than would suffice to cause an equal rise of temperature at a lower part of the thermometric scale; in other words, of a given quantity of heat imparted to a body near its melting point, a larger proportion goes to produce molecular modifications (expansion, softening, &c.), and a smaller proportion to produce rise of temperature, than is the case at a lower part of the scale. From this point of view, it becomes quite conceivable that, at some particular temperature, depending on the nature of the substance under consideration, the whole quantity of heat communicated to a body might be expended in causing molecular changes (change of the state of aggregation, with or without change of volume, &c.), so that its effect in producing a rise of temperature would be imperceptible. This is exactly what takes place during the melting of solid bodies.

From these considerations we see that the phenomenon indicated in the second law of the passage from the solid to the liquid state of aggregation (p. 74), is one which attains its maximum degree of development at the point of actual liquefaction, but is the same in kind as what occurs at lower temperatures. We see also that the fusion of glass and other bodies which have no definite melting point, but in which liquefaction occurs gradually and extends over a greater or less interval of temperature, does not differ in any essential respect from the sudden melting of ice at the fixed temperature of 0° C. In the case of glass, a certain small proportion of the total quantity of heat imparted to it during its liquefaction, is expended in causing elevation of temperature; in the case of ice, this proportion is so small as to be imperceptible in comparison with that which goes to cause liquefaction.

It was formerly supposed that the temperature of a body was always proportional to the heat contained in it, and therefore that heat could not be communicated to a body without raising its temperature. The cessation of the rise of temperature during the fusion of solids was first observed by Black, while Professor of Chemistry in the University of Glasgow. He ascertained that, during this process, a considerable quan-

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tity of heat, different for different substances, disappears so far as the production of thermometric effects is concerned—or, as he expressed it, becomes *latent*—and that an equal quantity of heat appears during solidification. According to modern views, the expression *latent* (or hidden) *heat* is not strictly correct, for the effect of heat imparted to ice at the melting point is just as visible, though not the same, as that which it produces at other temperatures. Nevertheless, the expression is convenient from the fact of its being universally recognised and employed. The latent heat of fluidity is, then, the quantity of heat which must be imparted to one gramme of a solid at its melting point in order to melt it without raising its temperature, or which must be withdrawn from a liquid at its freezing point, in order to render it solid without lowering its temperature.

The following table gives the melting points and latent heats of fluidity, expressed in ordinary heat-units (gramme-degrees), of various substances, according to the determinations of Person (Ann. Ch. Phys. [3] xxvii. 250):—

Latent Heats of Fluidity.

Substance.	Melting Point.	Latent Heat.	Substance.	Melting Point.	Latent Heat.
Mercury . .	−39°	2·82	Tin . . .	235°	14·25
Phosphorus . .	44	5·0	Silver . . .	1000	21·1
Lead . . .	332	5·4	Zinc . . .	433	28·1
Sulphur . . .	115	9·4	Chloride of calcium ($CaCl_2 3H^2O$)	28·5	40·7
Iodine . . .	107	11·7			
Bismuth . .	270	12·6	Nitrate of potassium	339	47·4
Cadmium . .	320	13·6	Nitrate of sodium .	310·5	63·0

The latent heat of water was found by Regnault and by Provostaye and Desains to be 79° C. According to Person, this number denotes the quantity of heat required to convert ice at 0° C. into water, but not the total quantity of the latent heat in the water, inasmuch as a certain additional portion of heat is rendered latent as the temperature of the ice rises from −2° to 0° (Ann. Ch. Phys. [3] xxx. 73). In six experiments on the fusion of ice previously cooled to between −2° and −21° C., the latent heat was found to vary between 79·9° and 80·1°, the mean quantity being 80°. Regnault also found greater values for the latent heat of water, as the ice had been cooled to a lower temperature. According to Hess, the true latent heat of water is 80·34° C. It has been proved by E. Desains (Ann. Ch. Phys. [3] lxiv. 419) that when water is cooled below 0° without freezing, the quantity of heat needed, in order to raise the temperature of a given weight from $s°$ below zero to $t°$ above zero, is the same whether the water remains liquid all the time, or whether it first freezes and afterwards melts again.

It is interesting to compare these values of the latent heat of water with those found by Black in 1762 (*Lectures on the Elements of Chemistry*, 2 vols. 4to. Edinburgh, 1803: vol. i. pp. 120–127). In one experiment, this philosopher measured the time required for the conversion of a known quantity of ice at 32° F. into water at 40° F. in a room of which the temperature remained constantly at 47° F., and compared it with the time during which the temperature of an equal weight of water rose under similar circumstances, from 33° F. to 40° F. He thus obtained for the latent heat of water the number 139° F., equal to 77·2° C. In another experiment, he melted 119 parts of ice at 32° F. by immersing it in 135 parts of water at 190° F., and so obtained 254 parts of water at 53° F. Hence, taking into account the different specific heats of the water and of the glass in which it was contained, he deduced the number 143° F., equal to 79·44° C.

The method adopted by Black in the second of these experiments is essentially the same as that still employed for the determination of latent heats of fluidity. A known weight of the substance to be examined is heated to a known temperature, and then immersed in the water (or other liquid) of a calorimeter, the temperature of which is such as to cause the substance to melt if solid, or, if liquid, to solidify; and when uniformity of temperature is established in the calorimeter, this temperature is determined. The experiment is therefore quite similar to the determination of the specific heat of a substance by the method of mixtures; the same apparatus may be used and the same precautions require to be taken in the two cases (see pp. 25–29).

In such an experiment let

A be the weight of water in the calorimeter, the water-equivalents of the calorimeter and thermometer supposed included;

W, the weight of substance operated upon;

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t, the initial temperature of the calorimeter;
θ, the final temperature of the calorimeter;
T, the initial temperature of the substance;
$\mathfrak{T}$, its melting (or freezing) point;
C, the specific heat of the substance in the solid state between the temperatures $\mathfrak{T}$ and θ;
c, its specific heat in the liquid state between the temperatures T and $\mathfrak{T}$; and
L its latent heat of fluidity.

Suppose that the experiment is made upon a melted substance which gives out heat to calorimeter and solidifies in it: then it is plain that the quantity of heat $A(\theta - t)$ absorbed by the calorimeter is made up of three parts—first, the heat lost by the substance in cooling from its original temperature to its freezing point; secondly, the heat given out by it during solidification; thirdly, the heat which it loses while cooling from its freezing point to the final temperature of the calorimeter. That is, $A(\theta - t) = W[c(T - \mathfrak{T}) + L + C(\mathfrak{T} - \theta)]$;

whence $$L = \frac{A}{W}(\theta - t) - c(T - \mathfrak{T}) - C(\mathfrak{T} - \theta).$$

The manner in which this formula will require to be modified, in order that it may apply to the case of a solid substance which is melted in the calorimeter by absorbing heat from it, need not be specially pointed out.

Changes of Volume accompanying Fusion and Solidification.—The accelerated rate of expansion exhibited by most solids as they approach their melting points, is in most cases followed by a further expansion during the actual process of liquefaction, so that the melted substance occupies a greater bulk than the solid of the same temperature from which it is formed. This phenomenon has been particularly studied by Kopp (Ann. Ch. Pharm. xciii. 129), whose principal results are as follows:

Phosphorus (the yellow modification of specific gravity 1·826 at 10°), expands uniformly up to its melting point (44°), at which temperature its volume is 1·017 of what it was at 0°; when melted, its volume at the same temperature is 1·052 of the volume at 0°. Hence 100 vols. solid phosphorus at 44° become 103·4 vols. liquid phosphorus at the same temperature.

Sulphur (native crystals, specific gravity 2·069) expands irregularly near its melting point (115°). Its volume being 1 at 0°, is 1·010 at 50°; 1·037 at 100°; 1·096 at 115°; at the moment of fusion, the expansion amounts to 5 per cent., the volume then increasing to 1·150.

Wax (bleached bees'-wax, specific gravity 0·976 at 10°) expands very rapidly as it approaches its melting point (64°), but only 0·4 per cent. more at the moment of fusion. If the volume at 0° is 1, the volume at 50° is 1·068; at 60°, is 1·128; at 64°, is 1·161, and increases by fusion to 1·166.

Stearic acid (pure, specific gravity nearly 1·0 at 10°) expands less than wax before melting, but then expands as much as 11·0 per cent. The volume at 0° being 1, it is 1·038 at 50°; 1·054 at 60°; and 1·079 at 70°, at which temperature the acid melts, its volume increasing to 1·198.

Rose's fusible metal (2 pts. bismuth, 1 pt. tin, and 1 pt. lead; specific gravity 8·906 at 10°) expands, when heated from 0° to 59°, in the ratio of 1 to 1·0027; but contracts when further heated, its volume at 82° being equal to that at 0°, and at 95° equal to 0·9947; in melting, between 95° and 98°, it expands by 1·55 per cent., so that at 98° its volume is equal to 1·0101. This alloy, therefore, contracts from 59° up to its melting point.

Water presents a remarkable exception to the general rule, and expands at the moment of fusion, or contracts on melting by about 10 per cent. One volume of ice at 0° gives 0·918 volume of water at the same temperature, or 1 volume of water at 0° gives 1·102 volume of ice. Dufour found, as the mean of 24 experiments, the density of ice at 0° equal 0·9175, that of water at the same temperature being 1. Brunner found for the density of ice the number 0·918.

Solid hydrated salts, on the contrary, expand at the moment of fusion, *e.g.* chloride of calcium ($CaCl^2.6H^2O$), by 9·6 per cent.; ordinary phosphate of sodium ($PNa^2HO^4.12H^2O$) and hyposulphite of sodium ($S^2Na^2O^3.5H^2O$) each by 5·1 per cent.

The expansion which takes place in water at the moment of solidification affords an explanation of several important phenomena. In the first place, it enables us to understand why increase of pressure should retard the freezing of water, instead of facilitating it, as it does that of most other liquids. Since the tendency of both heat and pressure is to diminish the bulk of water at 0°, and therefore to oppose the change of volume that occurs on freezing, it is easily conceivable that the one influence may (at least within certain limits) replace the other, and that a strong pressure applied to water at or below 0° may as effectually prevent its solidification, as the communication

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of heat which would raise its temperature above the freezing point. In the case of substances whose volume in the solid state is less than their volume in the liquid state, pressure acts in the opposite sense to heat, and therefore retards liquefaction and promotes solidification.

This same phenomenon is the cause of the powerful mechanical effects which occur when water freezes in a confined space. The bursting of water-pipes, and the breaking of jugs containing water, during frosty weather, are among the most familiar of these effects; and to these may be added the splitting of rocks by the freezing of water in their fissures and the swelling up of moist ground during frost.

The force with which water expands when cooled, and at the moment of becoming ice, is strikingly illustrated in the experiments made by Major Williams, at Quebec. Having filled a 13-inch iron bomb-shell with water, he closed the hole left for introducing the fusee by driving firmly in an iron plug weighing nearly 3lbs., and exposed it in this state to the frost. After some time, the iron plug was forced out with a loud explosion and thrown to a distance of 415 feet, and a cylinder of ice, 8 inches long, issued from the opening. In another experiment, the shell burst before the plug was driven out, and in this case a sheet of ice spread out all round by the crack. If we take into consideration the experiments of W. Thomson and Mousson already recorded (p. 75), it seems probable that some of the water must have remained liquid in these experiments, up to the moment when the resistance was overcome; that it then issued from the shell in the liquid state, but at a temperature below 0°, and therefore instantly began to solidify when the pressure was removed, and so retained the shape of the orifice whence it issued.

Bismuth, cast iron and antimony expand like water on becoming solid.

Solution of Solid Bodies in Water.—Very many solid substances are capable of dissolving in water, and thus forming with it a uniform mixed liquid. As a general rule, the solvent power of water increases with its temperature, but this is not universally the case; for example, chloride of sodium has very nearly the same solubility in cold water that it has in boiling water; lime-water saturated at 0°, contains nearly twice as much lime as can be dissolved by the same quantity of water at 100°. Several other calcium-compounds exhibit similar properties; thus the sulphate is more soluble in cold than in boiling water, and becomes quite insoluble in water between 140° and 150° (Cousté, Ann. des Mines, [5] v. 143). Sulphate of sodium is more soluble in water at 33° than at other temperatures, higher or lower, and has about the same solubility at 0° that it has at 100°. From the experiments of Sullivan (Rep. Brit. Association, 1859, p. 292) it appears that the solubility of very many salts attains a maximum at some particular temperature, above which it diminishes. Hence, perhaps, the reason why the solubility of most solids is commonly supposed to increase continuously as the temperature rises, is that it has been determined only at temperatures below 100°, and that the points of maximum solubility for most substances lie higher. If this be so, the solubility of sulphate of sodium,—and of the few other salts (selenate of sodium, sulphate of iron) in which similar properties have been observed,—is only in so far anomalous, that its temperature of maximum solubility is lower than that of most other substances. Water which is saturated at a given temperature with one substance can usually dissolve an additional quantity of another.

The liquefaction of solid bodies by solution in liquids, obeys essentially the same laws as their liquefaction by the direct application of heat. It is facilitated or retarded in the same way by great variations of pressure, and is attended by the absorption of a certain quantity of heat, which is evolved again when the dissolved substance separates from solution in the solid form; usually also the volume of the solution differs from the combined volumes of solid substance and water at the same temperature; and, lastly, solutions present the phenomenon of supersaturation, analogous to that of the deferred solidification of liquids.

As might be expected from the analogy with the liquefaction of solid bodies in general, increased pressure favours solution in cases where, as is usual, the volume of the water and dissolved substance is less after solution than the volume of the water and substance when separate; and diminishes the solubility of substances whose volume when dissolved is greater than their volume in the solid state, together with that of the water. (Comp. Sorby, Proc. Roy. Soc. xii. 538, also, Möller, Jahresber. 1862, pp. 11–13.)

The absorption of heat which occurs during solution is taken advantage of by the chemist for the artificial production of low temperatures. The table on the next page gives a few of the most frequently useful freezing mixtures, with the reduction of temperature which can be produced by means of each. In order to obtain the greatest possible effect by the use of any of these mixtures, it is necessary to use a considerable quantity of the materials (2 or 3 pounds at least); otherwise the whole heat required for the liquefaction is furnished by the containing vessel, and the whole of the mixture

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becomes liquid before its temperature has been much reduced. It is also of importance that the materials should be mixed as intimately as possible. Other more powerful freezing mixtures, depending on the employment of condensed gases, will be described hereafter.

Table of Freezing Mixtures.

Ingredients of the Mixture.	Parts by Weight.	Temperature produced, starting from 10°.	Diminution of Temperature.
Water	1	−16°	26°
Nitrate of ammonium	1		
Water	16	−12°	22°
Nitrate of potassium	5		
Chloride of ammonium	5		
Water	1	−19°	29°
Nitrate of ammonium	1		
Carbonate of sodium	1		
Snow, or pounded ice	5		20°
Chloride of sodium	2		
Snow, or pounded ice	1		45°
Crystallised chloride of calcium	2		
Crystallised sulphate of sodium	8	−20°	30°
Hydrochloric acid	5		

From a table already given (p. 60), it will be seen that water containing saline substances in solution freezes at a lower temperature than pure water, and that the depression of the freezing point increases with the quantity of substance in solution. This latter point is proved still more distinctly by the more recent experiments of Rudorff (Phil. Mag. [4] xxii. 552), from which it appears that the depression is very nearly in exact proportion to the quantity of salt dissolved. The ice which forms from a dilute solution of a salt yields nearly pure water when melted.

When a saturated solution is cooled, the excess of dissolved substance, beyond that which saturates the liquid at the lower temperature, generally separates out in the crystalline form; sometimes, however, especially if the solution is cooled slowly and is kept at perfect rest, a condition of unstable equilibrium may arise, like that of liquids cooled below their ordinary freezing points without solidifying, in which a greater quantity of substance is retained in solution than the liquid would be capable of dissolving if it were put in contact with it in the solid form. In this state, solutions are said to be supersaturated; and the same causes are in general sufficient to cause the separation of the excess of dissolved substance, as cause the solidification of over-cooled liquids.

If an aqueous solution of a salt is boiled in a flask of which the neck is drawn out to a fine point, and if the point is then hermetically sealed when all the air has been expelled, the solution very frequently remains supersaturated when cold; but on breaking the point, so as to readmit the air, even if this is done without shaking the solution in the least, or allowing the smallest fragment of glass to fall into it, crystallisation in most cases begins. If, however, the air that enters the flask has been previously passed through a red-hot tube, or even if it has been merely filtered through a column of cotton wool, crystallisation does not take place (comp. Loewel, Jahresber. 1852, p. 359; Schröder, Ann. Ch. Pharm. cix. 45; also particularly Gmelin's *Handbook*, i. 9–11). The most probable explanation of this difference is that the solid particles of soluble matter contained in the unheated or unfiltered air, disturb the molecular equilibrium of the solution by dissolving in it, and so cause crystallisation to begin. This explanation is confirmed by the fact that a supersaturated solution frequently does not crystallise if stirred with a glass rod or platinum wire which has been recently heated to redness, but crystallises instantly if touched with a rod that has lain long exposed to the air.

By cooling supersaturated solutions below 0°, they may be brought into such a condition, that either ice or the dissolved salt will crystallise out according to circumstances. Thus Rudorff found (*loc. cit.* and Pogg. Ann. cxvi. 55) that a small fragment of ice, thrown into a strongly cooled solution of platinocyanide of magnesium or sulphate of sodium, caused a crystallisation of ice, the whole of the salt remaining dissolved, until a very large proportion of the water had been transformed into ice; while a fragment of the solid salt thrown in caused the salt to crystallise, but no ice. The crystals of ice and of the salts used in these experiments were easily distinguishable by their

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different colours and specific gravities. These results are quite analogous to the simultaneous separate crystallisation of two or more salts contained in the same solution.

Vaporisation and Condensation.—When a quantity of water or alcohol is left exposed to the air, it gradually disappears, owing to its transformation into a transparent, invisible vapour, which diffuses into the atmosphere. This formation of vapour at the free surface of a liquid constitutes evaporation. It takes place more or less rapidly with all liquids, except some of those which are easily decomposed by heat when their temperature is sufficiently high. Some liquids, such as water, evaporate at all temperatures, but this is not the case with all: for instance, mercury gives off no sensible quantity of vapour at -10°, and two basins may be placed near each other, under an exhausted receiver, at the ordinary temperature, one containing oil of vitriol and the other a solution of chloride of barium, without the smallest precipitate being formed in the latter. Some solid bodies, *e.g.* ice, iodine, camphor, give off vapour without previously passing into the liquid state; and it is proved by Regnault's experiments (upon benzene, bromide of ethylene, glacial acetic acid, chloride of cyanogen, and chloride of carbon), that substances which are capable of existing at the same temperature either as solids or liquids, produce, in both states of aggregation, vapours of equal tension (see next paragraph).

Fig. 539.

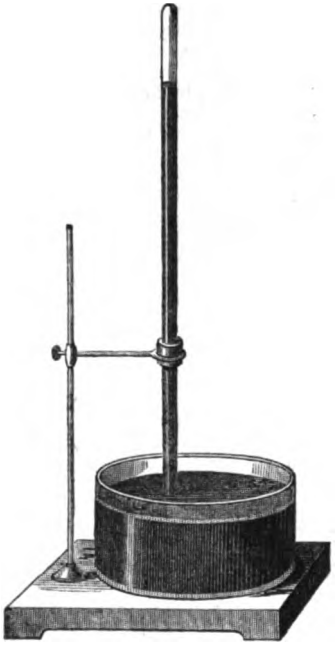


Fig. 540.



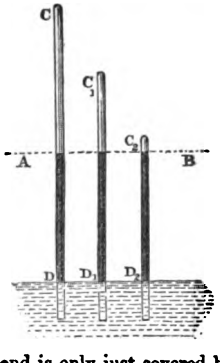
Tension of Vapours.—The quantity of any given liquid which can evaporate in an enclosed space, either previously vacuous or already containing a gas or vapour, is limited, and depends on the nature of the liquid, on the temperature, and on the extent of the enclosed space. When the liquid is in excess, that is, when some of it remains after the formation of the largest quantity of vapour that is possible under

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the circumstances, evaporation ceases when the vapour exerts a certain pressure upon the sides of the containing vessel. The laws of evaporation are, therefore, most easily arrived at by studying, in the first instance, the phenomena of the formation of vapour in a vacuum, in which case the pressure exerted by the vapour itself is the only one to which the sides of the vessel are exposed.

If a glass tube, closed at one end, about a yard long and three-quarters of an inch wide, is filled with mercury and inverted in a basin of that liquid, as shown in *fig.* 539, a vacuous space, about six inches in length, is formed at the top of the tube. On now passing up a drop or two of ether or alcohol into this space, the liquid will immediately evaporate, so that the surface of the mercury and of the tube will remain dry, but the mercury column will be depressed by the elastic force of the vapour which has been formed. The amount of this elastic force, or of the pressure which the vapour exerts upon the sides of the tube and upon the top of the column of mercury, is evidently measured by the difference between the height of this column and that of the barometer at the time of the experiment. On transferring the tube in this condition to a mercury-trough provided with a deep cylindrical well (*fig.* 540), and depressing it slightly, the space occupied by the vapour above the mercury will be diminished; the tension of the vapour will therefore increase, and the mercury column A C will be still further depressed. But on continuing to diminish in this way the volume of the vapour, a point will soon be reached at which part of it returns to the liquid state and condenses as a dew upon the inside of the tube and on the mercury; and if the height of the column A C be measured, as soon as the first trace of condensed liquid becomes visible, it will be found to remain the same until the tube has been depressed so far that the whole of the vapour has been converted into liquid, and the tube becomes filled with mercury, surmounted by a drop of liquid ether or alcohol. The progress of the experiment in this stage will be easily understood from *fig.* 541, where C D represents the tube when the liquid first begins to appear in the space above the mercury, and A B the level of the mercury in the tube above that in the trough. As the tube is depressed successively to the positions C_1 D_1, and C_2 D_2, more and more of the vapour is liquefied, but the remaining portion exerts neither more nor less pressure than the quantity which existed in the tube at the instant when liquefaction first began to take place; and hence the surface of the mercury remains immovably at the level A B. Again, if the tube is raised up out of the mercury, the top of the mercury column will still remain at the level A B, until the whole of the liquid has again evaporated into the space above it, but from this point it will begin to rise higher and higher as the tube is still further raised; if, however, when the tube has attained its highest position (so that the open end is only just covered by the mercury in the trough), an additional quantity of ether or alcohol is passed up into it, the column of mercury will sink; and if the quantity of liquid passed up is more than can evaporate in the portion of the tube unoccupied by the mercury, the surface of the latter will sink again to the level A B (*fig.* 541).

Fig. 541.



These experiments prove that when a vapour is compressed, its temperature remaining always the same, its elastic force increases up to a certain limit which it cannot exceed, the effect of any further compression being to change it to a liquid; and that when a vapour is in contact with any portion of the corresponding liquid, in a space otherwise vacuous, its elastic force always attains this limit, whatever may be the relative volumes of vapour and liquid. In this condition, a vapour is said to be **saturated**, or to exert its **maximum tension**.

Maximum Tension.—The maximum tension which the vapour of any liquid can exert depends upon the nature of the liquid, and upon its temperature.

If we pass up into the first of three barometric tubes, like that represented in *fig.* 539, a small quantity of ether, into the second some alcohol, and into the third some water, taking a larger quantity of each liquid than can evaporate completely within the tube, the mercury column will be depressed to a different level in each, supposing all three to have the same temperature. If, for instance, the temperature is 10° C., the mercury will be depressed about 11¼ inches in the first tube, nearly 1 inch in the second tube, and a little more than ⅓ inch in the third.

If the three tubes are now gradually heated, by surrounding them with warm water or otherwise, more vapour will be formed from the liquid contained in each of them; the elastic force or tension of each vapour will accordingly increase, and the mercury will descend lower and lower in the tubes as the temperature rises. At about 35°, the tension of the ether-vapour will have become equal to that of the atmosphere, and hence at this

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temperature, the mercury in the tube containing it will have been driven down so as to be at the same level as that in the reservoir; at about 78·5° the same will be the case with the mercury in the alcohol-tube; and at about 100° with that contained in the water-tube.

When a saturated vapour is cooled, the pressure upon it remaining unaltered, complete liquefaction takes place, just as it does when the pressure is increased and the temperature remains the same. The condition of saturation, or maximum tension, is therefore a limiting condition, beyond which a vapour can neither be compressed nor cooled without returning to the state of liquid.

On the other hand, when a saturated vapour not in contact with an excess of liquid is heated, it ceases to be saturated (unless the pressure upon it is increased at the same time to a corresponding extent). Hence, when a further quantity of liquid is brought in contact with a vapour which has been thus heated, more vapour is formed in the same space, until saturation is again produced, and the tension increases at the same time till it reaches the maximum tension corresponding to the higher temperature.

Distinction between Vapours and Gases.—It has been already stated, that when the space into which a liquid can evaporate is increased until the whole quantity of liquid has become vapour, the tension of the vapour diminishes with any further increase of volume; and that when a vapour, not in contact with the liquid from which it is formed, is compressed, its tension augments until liquefaction begins. In proportion as a vapour under these conditions is expanded, its tension becomes more and more nearly inversely proportional to the volume which it occupies; that is, its properties approach more and more nearly to those of a perfect gas. Similarly, when a saturated vapour, not in contact with an excess of liquid, is heated, its elastic force increases, and it expands if the pressure upon it is not proportionably augmented; and as the temperature rises, the relation between the tension or elastic force, p, of the vapour, its volume, v, and its temperature, t, comes to be more and more nearly expressed by the equation

$$pv = J(a + t);$$

which, as we have already seen (p. 45), expresses the relation between these three quantities in the case of a perfect gas (see also p. 50).

Hence the physical properties of vapours, when sufficiently expanded, and at sufficiently high temperatures, are identical with those of the permanent gases.

From this it is natural to conclude, conversely, that the so-called permanent gases themselves are only vapours which, at ordinary pressures and temperatures, are very far removed from their points of saturation, and that by exposing them to lower temperatures and increasing the pressure, a point might be reached for each of them, at which the pressure would be equal to the maximum tension which it was capable of exerting at the temperature of the experiment, and therefore, that any further diminution of temperature or increase of pressure would cause it to become liquid. This conclusion has been actually verified in the case of many gases formerly regarded as permanent, the only gases which have hitherto resisted all attempts to liquefy them being hydrogen, oxygen, nitrogen, nitric oxide, carbonic oxide and marsh-gas. (The methods employed for the liquefaction of gases will be further considered in connection with the processes adopted for obtaining great reductions of temperature.)

Tension of Vapours in presence of Permanent Gases.—The familiar fact of the evaporation of water in the open air affords sufficient proof that the presence of a permanent gas in any given space does not prevent volatile liquids giving off vapour into the same space. By measuring the volume and elastic force of a given quantity of dry air, or other gas, then introducing a little more of any liquid than can completely evaporate in it, and when equilibrium has been re-established, again measuring the volume and elastic force of the mixture of gas and vapour, the tension of the latter can be ascertained. In this way it has been found that, when the liquid exerts no solvent or chemical action upon the gas, the combined tension of gas and vapour is nearly equal to the separate tension of the gas, increased by the maximum tension which the vapour is capable of exerting in an otherwise vacuous space at the temperature of the experiment. In other words, the vapour given off by a liquid at any temperature has nearly the same maximum tension, whether it is formed in a space previously vacuous or filled with a permanent gas. The only essential difference between the evaporation of a liquid in a vacuum, and its evaporation in a gas, is that, in the former case, the vapour attains the condition of saturation in an inappreciably short time, while in the latter, this condition is arrived at more slowly. Regnault's experiments (Mém. Acad. Sciences, xxvi.) prove, however, that liquids do not give off vapour of quite so great a tension in a space occupied by a permanent gas, as they do in a vacuum, and that the difference increases as the temperature rises.

Boiling Points.—Ebullition.—From the facts stated in the last paragraph, it follows

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that the temperature at which the vapour of a liquid introduced into the barometric vacuum would exert sufficient elastic force to drive the mercury down to the bottom of the tube, so as to make it stand at the same level inside and outside, is also the temperature at which the vapour formed on heating the liquid in the air would exert an elastic force equal to the atmospheric pressure. As already stated, the first of these effects is produced by ether-vapour at 35°, by alcohol at 78·5°, and by water at 100°: these temperatures, however, are those at which the liquids respectively boil when heated in the open air, the barometer being at its average height. The boiling point of a liquid is, therefore, the temperature at which the tension of its vapour becomes equal to the atmospheric pressure. This temperature is evidently not absolutely constant for each liquid, but varies more or less with alterations of the pressure of the atmosphere. A liquid at its boiling point is in a limiting condition, comparable to that of a saturated vapour; any diminution of pressure or increase of temperature equally causes it to pass from the liquid to the vaporous state. The two conditions are in fact conterminous; and the temperature at which a liquid produces vapour of any given maximum tension, is also the temperature at which the liquid would boil under an atmospheric pressure equal to that tension. Hence the observation of the pressures under which a liquid boils at various temperatures constitutes a method of determining the maximum tension of its vapour at those temperatures.

The phenomenon of ebullition, which presents itself when heat is applied to the lower part of a mass of liquid, already at such a temperature that the tension of its vapour is equal to the pressure of the atmosphere, results from the transformation of the liquid into vapour at the points where the heat is applied, and the escape of this vapour in the form of bubbles through the superincumbent liquid.

The temperatures at which different liquids boil, under the ordinary atmospheric pressure, vary very greatly. They will be found given for each liquid in the article of this dictionary wherein it is specially described; in the following table a few boiling points are given in order to illustrate the range of temperature through which they occur.

Table of Boiling Points.

Liquid.	Boiling Point.	Pressure in millimetres of mercury.	Authority.
Nitrous oxide . .	−87·9°	759	Regnault
Carbonic anhydride .	−78·2	767·3	„
Ammonia . . .	−33·7	749·3	Bunsen
Sulphurous anhydride	−10·5	744	„
Chloride of ethyl .	+11·0	758	Pierre
Oxide of ethylene .	13·5	746·5	Wurtz
Aldehyde . . .	19·8	734	Kopp
Ether . . .	34·2	742	„
Sulphide of carbon .	47·9	755·8	Pierre
Methylic alcohol .	61·0	754	Delffs
Bromine . . .	63·0	760	Pierre
Alcohol . . .	78·4	760	Gay-Lussac
Benzene . . .	80·4	752	Kopp
Water . . .	100·0	760	„
Acetic acid . .	116·9	750	„
Cymene . . .	177·5	744	„
Naphthalene . .	216·8	747·6	„
Phosphorus . .	290	. .	Pelletier
Oil of vitriol . .	325	. .	
Mercury . . .	350	. .	Regnault
Sulphur . . .	440	. .	{Dumas; Deville and Troost
Cadmium . . .	860	. .	Deville and Troost
Zinc	1040	. .	„

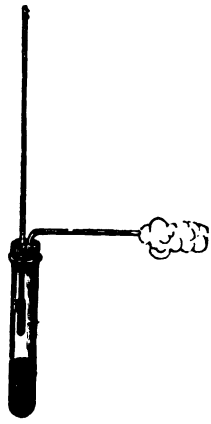
Determination of Boiling Points.—The boiling points of different liquids being among their most characteristic properties, the determination of them becomes a very frequent and important operation in chemical research. The method recommended by Kopp, in order to ensure as much accuracy as possible in these observations, is as follows:—

The liquid to be examined is placed in a cylindrical glass vessel, containing a few scraps of freshly ignited platinum foil, the diameter of which, when the quantity of liquid is small, need not much exceed that of the bulb of the thermometer. This vessel is closed by a cork, through the centre of which the thermometer is inserted, in such a way that it can be raised or lowered, so that the bulb may dip either into the liquid or

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merely into the vapour. It is generally advisable to give the thermometer the latter position, since, as will be seen by what follows, the temperature of the liquid may, under circumstances which not unfrequently occur, rise somewhat above the true boiling point; but even when this is the case, a thermometer in the vapour will show the real boiling point of the liquid: under nearly all circumstances, the thermometer will stand lower in the vapour than it does in the liquid, if this is a mixture of two or more liquids of different boiling points instead of a pure, homogeneous substance. Through a second hole in the cork is inserted a glass tube, open at both ends, and bent at a right angle, as shown in *fig.* 542; by connecting this tube with a condenser, the loss of the liquid used for the experiment can be prevented. The liquid is heated either by applying a small flame to the outside of the vessel, or by means of a water-bath or sand-bath, care being taken that the sides of the vessel above the liquid do not get over-heated. The indications of the thermometer are observed during the whole time that the liquid is being slowly boiled away, until only a small quantity remains. The temperature thus observed is not, however, in most cases, the true boiling point of the liquid: usually, part of the mercury column in the thermometer rises above the cork, and is therefore exposed to a lower temperature than that of the boiling liquid; consequently, the upper extremity of the column stands at a lower point than it would do if the thermometer were completely immersed in the liquid. In order to find the correction which it thus becomes necessary to apply, a second thermometer is placed so that its bulb is in contact with the stem of the thermometer inserted into the cork of the boiling vessel, and is half way between the top of the mercury column of the latter thermometer and the middle of the cork. The temperature indicated by this second thermometer may be taken as the mean temperature of that portion of the mercury column of the principal thermometer which is not heated by the vapour of the boiling liquid. Let this temperature be $t°$; let the uncorrected boiling point, directly indicated by the principal thermometer, be $T°$; let N be the difference between T and the point of the scale situated at the middle of the cork, that is to say, the length, expressed in degrees of the scale, of that portion of the mercury column of the principal thermometer of which the mean temperature is $t°$; lastly, let δ be the coefficient of apparent expansion of mercury in the glass of which the thermometer is constructed. The correction to be applied to the directly observed temperature $T°$ is then

Fig. 542.



$$= N(T-t)\delta.$$

As already stated (p. 57), δ may always be taken, in calculating the value of this expression, as $= 0{\cdot}0001545$.

The table which follows on p. 86 gives the amounts of the correction in question for various values of N and of $T-t$. The amounts corresponding to other values of these factors can be easily deduced by interpolation from the numbers given in the table.

This table sufficiently shows that the correction in question can never be neglected in accurate experiments, and that in the case of liquids of high boiling points, its value may become very considerable.*

Since the boiling point of a liquid depends on the pressure to which the liquid is subjected, another correction becomes necessary in order to reduce determinations made under the varying pressure of the atmosphere, to the values which would be found if the atmosphere exerted always its normal pressure, equal to that of 760 millimetres of mercury at 0°. Strictly speaking, the correction to be applied to the boiling point of a liquid observed under an atmospheric pressure differing by a given amount from the above standard pressure, varies with the nature of the liquid; since equal alterations of pressure do not cause precisely equal changes in the boiling points of different liquids. Nevertheless, the greatest variations which ever occur in the pressure of the atmosphere are relatively so small, that they may, without any appreciable error, be regarded as affecting the boiling points of all liquids equally: to the extent, namely, of 0·1° for a variation of pressure of 2·7 millimetres of mercury, this number being deduced from direct determinations of the boiling point of water under different pressures.

In what follows, whenever the boiling point of a liquid is spoken of without further explanation, it is to be understood to mean the boiling point under a pressure equal to that of 760 millimetres of mercury at 0°.

* It is obvious that a precisely similar correction ought to be applied to all thermometric observations in which any portion of the mercury in the stem of the thermometer is at a different temperature from that in the bulb.

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Table for the Correction of Boiling Points. (Kopp.)

$T-t$	N																			
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
10	0·02	0·03	0·05	0·06	0·08	0·09	0·11	0·12	0·14	0·15	0·17	0·18	0·20	0·22	0·23	0·25	0·26	0·28	0·29	0·31
20	·03	·06	·09	·12	·15	·18	·22	·25	·28	·31	·34	·37	·40	·43	·46	·49	·52	·56	·59	·62
30	·05	·09	·14	·18	·23	·28	·33	·37	·42	·46	·51	·55	·60	·65	·70	·74	·79	·83	·88	·92
40	·06	·12	·18	·25	·31	·37	·43	·50	·56	·62	·68	·74	·80	·86	·92	·99	1·05	1·11	1·17	1·23
50	·08	·15	·23	·31	·38	·46	·53	·62	·70	·77	·85	·92	1·00	1·08	1·16	1·23	1·31	1·39	1·46	1·54
60	·09	·18	·28	·37	·46	·56	·65	·74	·83	·92	1·01	1·11	1·20	1·29	1·39	1·48	1·57	1·66	1·76	1·85
70	·11	·22	·33	·43	·53	·65	·76	·87	·97	1·08	1·19	1·29	1·40	1·51	1·62	1·72	1·83	1·94	2·05	2·16
80	·12	·25	·37	·50	·62	·74	·87	·99	1·11	1·23	1·36	1·48	1·60	1·72	1·85	1·97	2·09	2·22	2·34	2·46
90	·14	·28	·42	·56	·70	·83	·97	1·11	1·25	1·39	1·52	1·66	1·80	1·94	2·08	2·22	2·36	2·49	2·63	2·77
100	·15	·31	·46	·62	·77	·92	1·08	1·23	1·39	1·54	1·69	1·85	2·00	2·16	2·31	2·46	2·62	2·77	2·93	3·08
110	·17	·34	·51	·68	·85	1·01	1·19	1·36	1·52	1·69	1·86	2 03	2·20	2·37	2·54	2·71	2·88	3·05	3·22	3·39
120	·18	·37	·55	·74	·92	1·11	1·29	1·48	1·66	1·85	2·03	2·22	2·40	2·59	2·77	2·96	3·14	3·33	3·51	3·70

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Circumstances which modify the Boiling Point.—Although, when a liquid is heated in such a manner that vapour can escape freely from some part of its surface, the vapour so formed has a tension equal to the pressure upon the free surface of the liquid as soon as the temperature of the latter reaches the boiling point, this temperature may nevertheless be attained, and even considerably exceeded, without the formation of a trace of vapour, if no portion of the surface of the liquid is freely exposed. These conditions can be realised by suspending the liquid to be examined in a second liquid of equal specific gravity, but higher boiling point.

The phenomena which take place under these circumstances have been particularly studied by Dufour (Ann. Ch. Phys. [3] lxviii. 378). In order to examine them in the case of water, he employed a mixture in the requisite proportions of oil of cloves (previously heated alone to about 200°) and linseed oil. The water, already heated to 80° or 90°, was dropped gently into the mixture of oils, so as not to disturb the film which coated the bottom of the vessel, and the temperature of the bath was gradually raised. Under these circumstances the ordinary boiling point of water, 100°, was passed without the occurrence of any perceptible change, and traces of ebullition scarcely began to show themselves below 110° or 115°. Even at these temperatures, ebullition seldom began except when the globules of water came in contact with the sides of the vessel or with the thermometer. A burst of vapour then occurred, and the globule, more or less diminished in size, was driven rapidly away, like a pith ball after touching an electrified conductor. These contacts were of course more difficult to avoid in the case of large than of small globules; hence the latter remained liquid, as a rule, to higher temperatures than the former.

In these experiments, it was a rare exception when ebullition occurred between 100° and 110°; very commonly globules of 10 mm. in diameter reached 120° or 130°, and in one experiment the last temperature was attained by a globule of 18 mm. diameter, and therefore containing more than 3 c. c. of water. Spheres of 10 or 12 mm. diameter often reached 140°; those of 5 or 6 mm. reached 165°; and others of from 1 to 3 mm. attained 175° or even 178°, temperatures at which the elastic force of the vapour which forms at the freely exposed surface of water is between 8 and 9 atmospheres.

At these high temperatures, the contact of a solid body very generally occasioned the sudden partial or complete vaporisation of the globules, accompanied by a hissing sound like that produced on immersing red-hot iron in water. This invariably occurred when the globules were touched with pieces of wood or chalk, shreds of cotton, paper, &c., but not always on contact with a glass rod or metallic wire, the difference appearing to depend on the porous structure of the former substances. A platinum wire appeared to lose, to some extent, by frequent usage, the power of causing sudden vaporisation.

Sudden ebullition, amounting even to an explosion, if the temperature was above 120°, invariably occurred on passing the discharge of a Leyden jar or induction coil through a globule. A similar, but less violent, effect was produced by the passage of a weak galvanic current. These results are attributed by Dufour less to the contact of the globules with the conducting wires, than to the disengagement of gas at the extremities of the latter.

Saturated aqueous solutions of various salts—for example, chloride of sodium, sulphate of copper, nitrate of potassium, &c.—also remained liquid at temperatures much above their boiling points, when immersed in melted stearic acid resting on a layer of melted sulphur. In like manner, globules of chloroform (boiling point 61°), suspended in a solution of chloride of zinc, often remained liquid up to 97° or 98°; and globules of liquid sulphurous anhydride (boiling point −10·5°) could be heated in diluted sulphuric acid as high as +8°. In all these cases, the same causes that operated in the case of water, sufficed to occasion the sudden complete or partial conversion of the overheated globules into vapour.

These results throw important light upon the nature of ebullition, and seem to indicate that it is to some extent an accidental phenomenon. In order to understand them, we must remember that, the globules being surrounded on all sides by liquid, evaporation cannot go on at their surface in the ordinary way. They are, however, in a state of tension, or unstable equilibrium, such that a very slight cause may occasion the sudden formation of vapour of more than the atmospheric tension. The most effectual of such causes would obviously be the contact of a minute globule of air or other gas: this globule, however small, would be a space into which vapour could be given off, and this vapour, having an elastic force greater than the pressure (that of the atmosphere and the upper layers of the liquid) whereby the globule was prevented from expanding, would force back the liquid walls of the bubble of gas, suddenly converting it into a large bubble of steam. Hence the unfailing efficacy, in causing the ebullition of the overheated globules of liquid, of the passage of an electric current or the contact

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of porous substances, such as chalk, wood, paper, &c., which either allow air to esca from their pores when immersed in the heated liquid, or carry down into it sm globules of air adhering to them. These globules afford space for the *commencement* the formation of vapour, and this process being once begun, the space is increased the force of the vapour already formed within it. In the absence of any such spa the liquid globule is in a condition somewhat analagous to that of a drop of melted gl which has been suddenly cooled in water (Rupert's drops), and which falls to powd on receiving the smallest scratch: there is no reason why the formation of vapo should begin at one point of the mass rather than at another, and thus the whole remai in a state of molecular tension until something occurs at some particular point to weak the effect of the forces which oppose the formation of vapour, or until the tensi increases (in consequence of rise of temperature) to such a degree that these forces a overcome simultaneously throughout the whole mass. It will be seen further on th these considerations exactly agree with the explanation which the mechanical theo of heat affords of the passage from the liquid to the gaseous state.

Even when liquids are heated in open vessels, the occurrence of ebullition, or t formation of vapour in the *interior* of the mass, appears to depend on like accident causes. Thus the influence of the nature of the vessel wherein a liquid is contain has been long recognised. It has been observed, for instance, that water, which w boil steadily at 100° in a metallic vessel, may often be heated to 105° or 106° witho boiling, in a glass vessel previously washed with strong sulphuric acid. Under the circumstances, ebullition generally takes place very irregularly: at a certain temper ture a sudden burst of vapour occurs, and the temperature of the liquid falls at the sa time to nearly the normal boiling point; the liquid then remains tranquil for a tim until the temperature having again risen considerably, another burst of vapour tak place, and so on. The "bumping" of heated liquids which results from this inte mittent formation of vapour, is familiar to every chemist. It may be prevented to son extent by putting into the liquid a few scraps of platinum, or a globule of mercury; small piece of charcoal is, however, much more effectual than either of these, though n always admissible. This irregular ebullition occurs much more frequently in son liquids than others, and to a greater extent in certain glass vessels than in others. F instance, methylic alcohol (boiling point 61°) may show a difference in its temperatu of ebullition amounting, according to Kopp, to 5 or 6 degrees, depending on the ves in which it is examined. When a liquid is boiling steadily in a glass flask or reto it may almost always be noticed that the bubbles of vapour start from one or t particular points of the surface of the glass, indicating the existence of some irregulari of the glass at those points favourable to the formation of vapour. Another illustrati of the necessity of some other cause than mere temperature in order to bring about t ebullition of liquids, is afforded by the remarkable observation of Professor Donny, Ghent, that water thoroughly deprived of air and sealed up in a rather long glass tu quite free from air, may be heated to 138° at one end of the tube without boiling, a is then suddenly and violently thrown to the other end by a burst of vapour. A additional fact of the same kind may sometimes be observed during the distillation liquids under the ordinary pressure. The writer has occasionally seen a liquid dis very rapidly, thus showing that vapour was being formed rapidly at the surface, althou ebullition could not be maintained by the use of a more powerful flame than th which had sufficed, at an earlier stage of the experiment, to boil a larger quantity the same liquid.

The whole of these phenomena cease to be unintelligible if, with Dufour, we disti guish between the boiling point of a liquid, and the temperature at which the elast force of its vapour becomes equal to the pressure of the atmosphere, and define t boiling point as the lowest temperature at which ebullition *can* occur, instead of as t temperature at which, under normal conditions, it *must* occur.

Spheroïdal State.—When a drop of water is allowed to fall upon a piece of iron, t temperature of which considerably exceeds 100°, it retains its globular form, mov about rapidly on the surface of the iron without wetting it, and evaporates with con parative slowness. As the iron cools, a point is reached at which the globule of wat wets it, spreads over its surface, boils and quickly disappears. The condition of t globule first described has been distinguished as the spheroïdal state. Th condition can be assumed by all volatile liquids when they come in contact with th surface of either a solid or a liquid body heated considerably above their boiling point The temperature of a liquid in the spheroïdal state is always below its ordinary boilin point, notwithstanding the higher temperature of the surface on which it rests. Th absence of ebullition is therefore due in this case to some other cause than that whic produces the phenomena of deferred ebullition which were considered in the last paragraph It is the result of a want of perfect contact between the liquid and the heated surfac Many experiments prove that the liquid globule rests upon a sort of cushion of its ow

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vapour, produced by the heat radiated from the hot surface against its under side. As fast as this vapour escapes from under the globule, its place is supplied by a fresh quantity produced in the same way, so that the globule is constantly buoyed up by it, and never comes into actual contact with the heated surface. If, however, the temperature of the latter is allowed to fall, the formation of vapour becomes less and less rapid, until at last it is not supplied fast enough to prevent the globule touching the hot metal or liquid on which it rests: as soon as contact occurs, heat is rapidly imparted to the globule, it enters into ebullition, and quickly boils away.

According to Boutigny's experiments, the lowest temperature at which a metallic vessel will cause the spheroïdal state to be assumed by water is 142°; for alcohol the lowest temperature is 134°, and for ether 61°.

Solid bodies which evaporate without becoming liquid also assume a condition analogous to the spheroïdal state of liquids, when they are placed upon a surface whose temperature is sufficiently high to vaporise them very rapidly. This is very distinctly seen on throwing a piece of solid carbonate of ammonium into a red-hot platinum crucible, and when a fragment of solid carbonic anhydride is placed upon any good conducting surface at the ordinary temperature.

Effect of Substances in Solution on the Boiling Point of Liquids.—Liquids holding solid bodies in solution boil generally at higher temperatures than they do in the pure state. On the other hand, the boiling point of water is lowered by mixing it with alcohol, and that of alcohol by mixing it with ether; the boiling point of a mixture being always intermediate between the boiling points of its components. The effect of salts in raising the boiling point of water may be considered as also coming under this rule. The following table gives the boiling points of saturated solutions of several salts, according to Legrand.

Table of Boiling Points of Saturated Saline Solutions.

Salt.	Weight of salt dissolved in 100 parts of water.	Boiling Point.	Salt.	Weight of salt dissolved in 100 parts of water.	Boiling Point.
Acetate of potassium .	798·2	169°	Tartrate of potassium .	296·2	114·7°
Nitrate of calcium .	362·2	151	Chlorate of potassium .	61·5	104·2
Carbonate of potassium	205·0	135	Chloride of sodium .	41·2	108·4
Acetate of sodium .	209·0	124·4	Phosphate of sodium (dried)	112·6	106·6
Nitrate of sodium .	224·8	121			
Chloride of strontium .	117·5	117·8	Carbonate of sodium .	48·5	104·6
Nitrate of potassium .	335·1	115·9	Chloride of barium .	60·1	104·4
Chloride of ammonium	88·9	114·2			

(For Legrand's determinations of the boiling points of weaker solutions of these and some other salts, and for the similar experiments of Griffiths and Faraday, see Gmelin's *Handbook*, i. 269, 270.)

Very contradictory opinions have been maintained by different observers with regard to the temperature of the vapour which issues from boiling saline solutions. It has been said, on the one hand, to be the same as that of pure water boiling under the same pressure; and, on the other hand, to be equal to that of the highest stratum of the solution. According to the recent experiments of Magnus (Pogg. Ann. cxii. 408), the latter statement appears to be nearest the truth. These experiments prove decisively that the vapour of boiling solutions is hotter than that of pure water, and that its temperature rises as the solutions become more concentrated, and therefore boil at higher temperatures; nevertheless, the vapour was always found a little colder than the mass of the boiling solution, and the difference was greater at high temperatures than it was at low ones.

Relations between the Boiling Point of substances and their Chemical Composition.—Many attempts have been made to trace some connection between the boiling points of different liquids and their chemical composition. The most extensive and important series of observations that have been made upon this point are due to Kopp (Ann. Ch. Pharm. xcvi. 2, 330; xcviii. 267, 367; Phil. Trans. 1860, 257). The principal conclusions deducible from these investigations are as follows:—

1. Analogous compounds, presenting the same difference of composition, very frequently differ by the same amount in their boiling points, or the interval between their boiling points is proportional to their difference of composition. A compound containing xC more or less than another of analogous function, generally boils at a

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temperature $x \times 29$ degrees higher or lower than the latter, and if it contains xH more or less it commonly boils at $x \times 5$ degrees lower or higher. A particular instance of the application of this rule is to homologous compounds: in the homologous acids $C^nH^{2n}O^2$ (Acids, i. 50), and in the corresponding alcohols and compound ethers, the addition of CH^2 to the formula of a compound raises its boiling point on an average by 19°, agreeing with the above rule.

2. An acid, $C^nH^{2n}O^2$, boils at a temperature 40° higher than the alcohol, $C^nH^{2n+2}O$ (Alcohols, i. 97), the oxidation of which may give rise to the acid.

3. A compound ether (Ethers, ii. 512), $C^nH^{2n}O^2$, boils at a temperature 82° lower than the acid, $C^nH^{2n}O^2$, isomeric with it.

If we start from the boiling point of ethyl-alcohol, = 78°, these three propositions enable us to calculate the boiling points of a large number of organic substances, alcohols, acids, and compound ethers, represented by the above general formulæ. The following tables serve to show how far the boiling points thus calculated correspond with those actually observed.

Boiling Points of Alcohols, $C^nH^{2n+2}O$.

Name.	Formula.	Calculated Boiling Point.	Observed Boiling Point.
Methylic alcohol .	CH^4O	59°	Kane, 60°; Delffs, 60·5°; Kopp, 65°; Pierre, 66°; Dumas and Péligot, 66·5°.
Ethylic alcohol .	C^2H^6O	78	Dumas and Boullay, 76°; Gay-Lussac, Pierre, Kopp, Delffs, Andrews, 78°.
Tritylic alcohol .	C^3H^8O	97	Chancel, 96°.
Tetrylic alcohol .	$C^4H^{10}O$	116	Wurtz, 109°.
Amylic alcohol .	$C^5H^{12}O$	135	Pasteur, 127°—129°; Cahours, Pierre, Kopp, Delffs, 132°; Rieckher, 136°.
Hexylic alcohol .	$C^6H^{14}O$	154	Faget, 148°—154°.
Heptylic alcohol .	$C^7H^{16}O$	173	Städeler, 177°—177·5°.
Cetylic alcohol .	$C^{16}H^{34}O$	344	Favre and Silbermann, 366°?

Boiling Points of Acids, $C^nH^{2n}O^2$.

Name.	Formula	Calculated Boiling Point.	Observed Boiling Point.
Formic acid . .	CH^2O^2	99°	Liebig, 99°; Bineau, Favre and Silbermann, 100°; Kopp, 105°.
Acetic acid . .	$C^2H^4O^2$	118	Delffs, 116°; Kopp, 117°; Sébille-Auger, 119°; Dumas, 120°.
Propionic acid .	$C^3H^6O^2$	137	Dumas, Malaguti, and Leblanc, about 140°; Limpricht, Kopp, 142°.
Butyric acid . .	$C^4H^8O^2$	156	Kopp, Delffs, 156°; Pierre, 163°; Pelouze and Gélis, about 164°.
Valeric acid . .	$C^5H^{10}O^2$	175	Dumas and Stas, Delffs, 175°; Kopp, 176°.
Caproic acid . .	$C^6H^{12}O^2$	194	Brazier and Gossleth, Wurtz, 198°; Fehling, 202°—209°.
Œnanthylic acid .	$C^7H^{14}O^2$	213	Städeler, 218°.
Caprylic acid . .	$C^8H^{16}O^2$	232	Fehling, 236°; Perrot, 238°.
Pelargonic acid .	$C^9H^{18}O^2$	251	Perrot, 225°; Cahours, 260°.

In other groups of compounds, a difference of CH^2 in the composition of analogous substances corresponds frequently to a nearly constant difference of boiling point: but this difference sometimes amounts to more than 19 degrees, and sometimes to less. For instance, in the series of hydrocarbons C^nH^{n-6}, homologous with benzene, C^6H^6, a difference of CH^2 in composition corresponds to an average difference of about 24° in boiling point; in the series of alcohol-radicles (or hydrides) C^nH^{2n+2}, homologous with ethyl, C^2H^{10}, (or marsh-gas, CH^4) the difference of boiling point corresponding to the same difference of composition, is also nearly 24°; in the series of acetones $C^nH^{2n}O$, it is about 22°. On the other hand, the difference of boiling point, corresponding to a difference of CH^2 in composition, is less than 19° in the anhydrides

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Boiling Points of Compound Ethers, $C^nH^{2n}O^2$.

Name.	Formula.	Calculated Boiling Point.	Observed Boiling Point.
Formate of methyl .	$C^2H^4O^2$	36°	Kopp, Andrews, 33°; Liebig, 36°—38°.
Acetate of methyl . / Formate of ethyl .	$C^3H^6O^2$	55	Andrews, 55°; Kopp, 56°; Dumas and Péligot, 58°. / Liebig, Delffs, 53°; Kopp, 55°; Löwig, 56°.
Acetate of ethyl . .	$C^4H^8O^2$	74	Dumas and Boullay, Pierre, Kopp, Delffs, 74°.
Butyrate of methyl / Acetate of trityl . / Formate of tetryl . / Propionate of ethyl	$C^5H^{10}O^2$	93	Favre and Silbermann, Delffs, 93°; Kopp, 95°; Pierre, 102°. / Berthelot, about 90°. / Wurtz, about 100°. / Kopp, 96°—98°; Limpricht and Uslar, 101°.
Valerate of methyl. / Butyrate of ethyl . / Acetate of tetryl . / Formate of amyl .	$C^6H^{12}O^2$	112	Kopp, 114°—115°. / Pelouze, 110°; Delffs, 113°; Kopp, 115°; Pierre, 119°. / Wurtz, 114°. / Delffs, 114°; Kopp, about 116°.
Valerate of ethyl . / Butyrate of trityl . / Acetate of amyl .	$C^7H^{14}O^2$	131	Delffs, 132; Otto, Kopp, Berthelot, 133°—134°. / Berthelot, about 130°. / Cahours, 125°; Kopp, Delffs, 133°.
Caproate of ethyl . / Propionate of amyl	$C^8H^{16}O^2$	150	Lerch, 120°; Fehling, 162°. / Wrightson, about 155°.
Butyrate of amyl . .	$C^9H^{18}O^2$	169	Delffs, 173°—176°.
Valerate of amyl . / Acetate of capryl .	$C^{10}H^{20}O^2$	188	Kopp, 188; Balard, about 196°. / Dachauer, 191—192°; Bouis, 193°.
Pelargonate of ethyl / Caproate of amyl .	$C^{11}H^{22}O^2$	207	Cahours, 216°—218; Delffs, 224°. / Brazier and Gossleth, 211°.
Laurostearate of ethyl	$C^{14}H^{28}O^2$	264	Görgey, 264°; Delffs, 269°.

$C^{2n}H^{4n-2}O^3$, homologous with acetic anhydride, $C^4H^6O^3$ (namely, about 12·5°); in the ethers of the acids $C^nH^{2n-2}O^4$, homologous with oxalic acid, $C^2H^2O^4$ (namely, about 14°); also in the carbonates, sulphocyanates and borates of the alcohol-radicles C^nH^{2n+1}.

These results seem to show that, as a rule, the greater the quantity of oxygen contained in any series of compounds, the smaller is the effect on the boiling point of a difference of composition amounting to CH^2.

In the chlorides, bromides and iodides of the alcohol-radicles C^nH^{2n+1}, a difference in composition of CH^2 causes a difference in boiling point of from 24 to 31 degrees; in the corresponding sulphides and sulphydrates (mercaptans) the difference also considerably exceeds 19°.

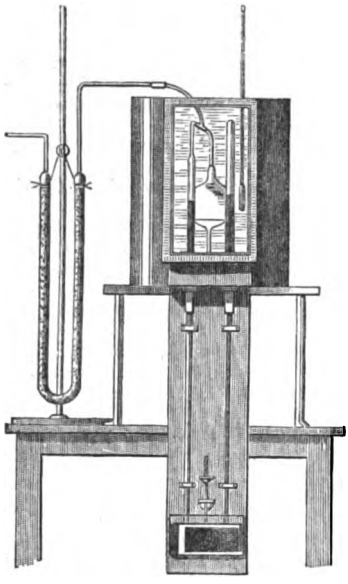
Measurement of the Tension of Vapours.—The various methods that have been employed for measuring the maximum tension of vapours at different temperatures, depend upon principles already explained. We have here to describe briefly the manner in which these principles were put in practice, and to state the most important results obtained.

The tension of vapours at temperatures below the ordinary boiling points of the corresponding liquids, and therefore at pressures less than that of the atmosphere, have been measured by determining the depression of the mercury column of a barometer produced by the saturated vapours at known temperatures. *Fig.* 543 represents the apparatus employed by Regnault (*Relation des Expériences*, &c. p. 489) in his principal series of experiments made by this method. The liquid whose vapour is to be examined is contained in a small bulb almost completely filled by it, and hermetically sealed without any trace of air. This bulb is introduced into a glass globe, the neck of which is then drawn out, bent at a right angle, and cemented into a narrow T-tube of copper, the other branches of which communicate, one of them through a drying tube containing pumice-stone and sulphuric acid, with an air-pump, the other, by a capillary tube, with the top of a wide glass tube open below and dipping into mercury. This last tube forms the barometer, the depressions of which are observed; its upper part

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is inside a metal water-bath, one face of which is formed by a sheet of plate glass, and in which are also contained the upper part of an ordinary barometer, to serve as a standard of comparison, and the glass globe spoken of above; this, as shown in the figure, rests on a metal ring carried by a support rising from the bottom of the bath. Previous to beginning the experiments, the inside of the glass globe and of the tubes communicating with it is rendered absolutely dry by repeatedly pumping out the air, and each time allowing it to be filled again by air dried by passing through the sulphuric acid drying tube. Then, by bringing a piece of hot charcoal near the outside of the globe, the bulb containing the liquid is burst, and the experiments are proceeded with by observing simultaneously the temperature of the bath in which the globe is immersed, and the difference in height of the two barometers.

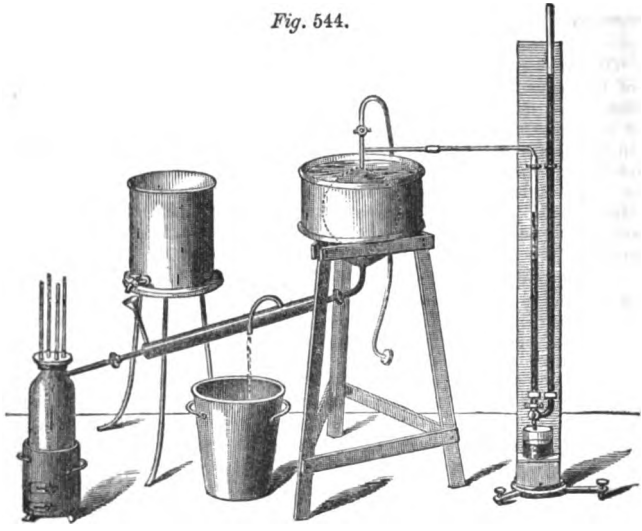
Fig. 543.



The same apparatus, slightly modified, served for the determination of the tension of vapours in presence of air or other gases.

For the determination of the tension of the vapour of water at higher temperatures, Regnault (*ibid.* p. 515) employed the apparatus represented in *fig.* 544, an apparatus which enabled him to measure the pressure under which water boiled at various temperatures (see p. 83). The apparatus consists of a copper retort, containing the water to be experimented upon, and communicating, through a tube surrounded by cold water (whereby the steam produced is condensed and whence it continually flows back as water into the retort), with a copper globe of 24 litres capacity. This globe is connected with a manometer which indicates the pressure inside the whole apparatus and

Fig. 544.



also with a branch tube by means of which air can be withdrawn from or forced into the apparatus, so as to bring the pressure to the required amount. The temperature of the boiling water in the retort is indicated by four thermometers, two of which dip into the water, and two into the steam. In order to prevent any alteration in the capacities of the bulbs of the thermometers, resulting from the pressure of the vapour upon them, they are enclosed in iron tubes, closed at the bottom and containing mercury.

The following table gives the results obtained at intervals of five degrees between

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− 32° and + 230°. (For tables of the tensions of water-vapour at each degree centigrade between these limits, and at each tenth of a degree between −10° and +35° and between 85° and 101°, see Regnault, *loc. cit.* pp. 624–633.)

Maximum Tension of Water-vapour between −32° *and* +230°. (Regnault.)

Temperature.	Tension, millimetres.	Temperature.	Tension, millimetres.	Temperature.	Tension, millimetres.
−32°	0·320	55°	117·478	145°	3125·55
30	0·386	60	148·791	150	3581·23
25	0·605	65	186·945	155	4088·56
20	0·927	70	233·093	160	4651·62
15	1·400	75	288·517	165	5274·54
10	2·093	80	354·643	170	5961·66
5	3·113	85	433·041	175	6717·43
0	4·600	90	525·450	180	7546·39
+ 5	6·534	95	633·778	185	8453·23
10	9·165	100	760·000	190	9442·70
15	12·699	105	906·410	195	10519·63
20	17·391	110	1075·370	200	11688·96
25	23·550	115	1269·410	205	12955·66
30	31·548	120	1491·280	210	14324·80
35	41·827	125	1743·880	215	15801·33
40	54·906	130	2030·280	220	17390·36
45	71·391	135	2353·730	225	19097·04
50	91·982	140	2717·630	230	20926·40

Determinations of the tension of water-vapour up to 111 degrees have also been made by Magnus (Pogg. Ann. lxi. 225) by a method essentially similar to the first of those above described. His results agree closely with those of Regnault. (For the older determinations of the pressure of steam at high temperatures by Arago and Dulong, see Gmelin's *Handbook*, i. 262.)

The following table, by Fairbairn and Tate (Phil. Trans. 1860, p. 220), gives the temperatures at which water is completely converted into saturated steam under various pressures, together with the volume of steam formed under these circumstances compared with that of the water from which it is produced.

Pressure, Temperature, and Volume of Saturated Steam.

Pressure.		Temperature.		Volume.
Inches.	Millimetres.	Fahrenheit.	Centigrade.	
5·35	135·9	136·77°	58·20°	8276·3
8·62	219·9	155·33	68·51	5333·5
9·45	240·0	159·36	70·76	4920 2
12·47	316·7	170·92	77·18	3722·6
12·61	320·2	171·48	77·49	3715·1
13·62	345·9	174·92	79·40	3438·1
16·01	406·6	182·30	83·49	3051·0
18·36	466·3	188·30	86·83	2623·4
22·88	581·2	198·78	92·66	2149·5
53·61	1361·7	242·90	117·16	943·1
55·52	1410·1	244·82	118·23	908·0
55·89	1419·6	245·22	118·45	892·5
66·84	1697·7	255·50	124·16	759·4
76·20	1935·4	263·14	128·41	649·2
81·53	2070·8	267·21	130·67	635·3
84·20	2138·9	269·20	131·77	605·7
92·23	2342·6	274·76	134·86	584·4
90·08	2287·9	273·30	134·05	543·2
99·60	2529·8	279·42	137·45	515·0
104·54	2655·2	282·58	139·21	497·2
112·78	2864·6	287·25	141·80	458·3
122·25	3105·1	292·53	144·74	433·1
114·25	2901·9	288·25	142·36	449·6

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The following tables contain the results of some of Regnault's experiments on the tension of the vapours of other liquids. (Mém. Acad. Sciences, xxvi. 349–658.)

Tension of Vapours.

Temperature.	Alcohol.	Ether.	Sulphide of carbon.	Chloroform.	Benzene.	Oil of turpentine.
° C.	mm.	mm.	mm.	mm.	mm.	mm
− 20	3·3	67·5	43·5	. .	4·9	
10	6·6	113·3	81·0	. .	13·4	
0	12·8	183·3	132·0	. .	26·6	2·1
+ 10	24·3	286·4	203·0	. .	46·6	2·9
20	44·5	433·3	301·8	160·5	76·3	4·4
40	133·6	909·6	617·0	366·2	182·3	10·8
60	350·3	1728·5	1163·7	751·0	388·6	26·5
80	812·8	3024·4	2033·8	1404·6	756·6	61·3
100	1694·9	4950·8	3329·5	2426·5	1352·3	131·1
120	3219·7	7702·2	5145·4	3916·2	2256·3	257·2
140	5637·0	. .	7556·9	5965·8	3537·0	464·0
150	7258·7	. .	. .	7226·5	4336·7	605·2

Tension of Vapours—continued.

Liquefied Gases.				Mercury.			
Temperature.	Sulphurous anhydride.	Ammonia.	Sulphydric acid.	Temperature.	Tension.	Temperature.	Tension.
° C.	mm.	mm.	mm.	° C.	mm.	° C.	mm.
−78·2	. .	240·0	441·4	0	0·0200	120	1·534
40	. .	528·6	. .	10	·0268	150	4·266
30	287·5	876·6	2808·6	20	·0372	180	11·00
20	479·5	1397·7	4273·0	30	·0530	200	19·90
10	762·5	2149·5	5945·0	40	·0767	250	75·75
0	1165·1	3162·9	7709·3	50	·1120	300	242·1
+10	1719·5	4612·2	10896·3	60	·1643	350	663·2
20	2462·0	6467·0	14151·5	70	·2410	400	1587·9
30	3431·8	8832·2	18035·3	80	·3528	450	3384·3
40	4670·2	11776·4	22682·5	90	·5142	500	6520·2
50	6220·0	. .	27814·8	100	·7455	520	8264·9

It was supposed by Dalton that the tension of the vapours of all liquids is the sam at temperatures equally distant from their respective boiling points. The observation from which the above tables are constructed show that this rule is not strictly true, bu is nearly so in most cases for small intervals of temperature above or below the boilin points: hence, in order to correct boiling point observations for the variations o atmospheric pressure, it may be assumed without sensible error that a difference o pressure equal to 2·7 millimetres of mercury causes a difference in the boiling point of all liquids, equal to that which it produces in the case of water,—namely, 0·1° C (see pp. 85 and 92.)

Tension of the Vapours of Mixed Liquids and of Saline Solutions.—Regnault' experiments on the tension of the vapour of mixed liquids prove that: (1) when tw liquids exert no solvent action upon each other, as *water* and *sulphide of carbon*, wate and *bichloride of carbon* (CCl^4), or water and *benzene*, the tension of the vapour whic rises from a mixture of them is very nearly equal to the sum of the tensions of the tw separate liquids at the same temperature; (2) with water and ether, which dissolv each other to some extent, but not in all proportions, the tension of the vapour of th mixture is much less than the sum of tensions of the separate liquids, being scarcel equal to that of ether only; (3) when the two liquids dissolve each other in all pr portions, as ether and sulphide of carbon, benzene and alcohol, water and alcohol, th tension of the vapour of the mixed liquid is intermediate between the tensions of th separate liquids.

The tension of the vapour of saline solutions has been examined by Regnault ar by Wüllner (Jahresber. 1858, 42–47; 1860, 47–49). Regnault's experiments we

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nade by means of the apparatus represented in *fig.* 543, p. 92; Wüllner employed a differently arranged apparatus, but one which depended on essentially the same principles. It results from these investigations that the tension of the vapour of a solution is less than that of the vapour of pure water at the same temperature, and that in the case of efflorescent salts and of salts that are permanent in the air, the diminution of the tension of the vapour emitted by the solution is exactly proportional to the quantity of salt dissolved in a constant weight of water, but in the case of deliquescent salts it is proportional to the quantity of hydrated salt dissolved: *e. g.*, for a solution of potash, to the quantity of $KHO.2H^2O$; for a solution of soda, to the quantity of $NaHO.1\frac{1}{2}H^2O$; for a solution of chloride of calcium, to the quantity of $CaCl^2.6H^2O$. The absolute amount of diminution of tension depends on the temperature, and becomes greater as the temperature rises.

Tension of Vapours in an unevenly heated space.—In an enclosed space, the temperature of which is different at different parts, the vapour of a liquid can assume a state of statical equilibrium only when its tension is equal to the maximum tension corresponding to the temperature of the coldest part of the space. If the vapour has, to begin with, a greater tension than this, liquefaction will take place in the coldest part, since the pressure is greater than that which the vapour can support at the temperature of this part, and this process will continue until the tension throughout the whole space is reduced to the point already stated. It is upon this principle that the process of distillation, and the action of the condenser of the steam engine, depend.

Complete Vaporisation of Liquids under great pressures.—When the temperature of a liquid is raised sufficiently high, vaporisation occurs under the highest pressure to which the substance can be subjected. Alcohol, ether, or rock-oil, enclosed in a tube of strong glass or iron, is completely converted into vapour only when the space not occupied by the liquid is somewhat greater than the volume of the liquid itself. With rock-oil the empty space may be somewhat smaller than with alcohol, and with ether still less. Alcohol when thus heated acquires increased mobility, expands to twice its original volume, and is then suddenly converted into vapour. This change takes place at 207° C. (404·6° Fah.), when the alcohol occupies just half the volume of the tube; if the tube is more than half filled with alcohol, it bursts when heated. A glass tube one-third filled with water becomes opaque when heated, and bursts after a few seconds. If this chemical action of the water on the glass be diminished by the addition of a little carbonate of soda, the transparency of the glass will be much less impaired; and if the space occupied by the water be $\frac{1}{4}$ of the whole tube, the liquid will be converted into vapour at about the temperature of melting zinc (Cagniard de la Tour).—If liquid carbonic anhydride sealed in a glass tube occupies $\frac{13}{30}$ of the volume of the tube at 0°, it neither increases nor diminishes in bulk when heated, because the increase of volume produced by heating is just compensated by the diminution caused by vaporisation. If it occupies $\frac{1}{2}$ of the space at 0°, its volume diminishes when it is heated, and increases when it is cooled, because the loss by evaporation preponderates over the expansion. If it takes up $\frac{2}{3}$ of the space, its volume increases by heat and contracts by cold, as in a thermometer; but at + 30° (86° Fah.) the whole is converted into vapour. The gas, which at 0° occupies the space above the liquid carbonic anhydride would, if condensed, yield $\frac{1}{12}$ of its volume of liquid acid; and that which is produced at + 30° would give $\frac{1}{3}$ ($\frac{1}{4}$? Gmelin) of its volume of liquid carbonic anhydride at 0°. (Thilorier.)

When chloride of ethyl was heated in a very thick sealed tube, the upper surface ceased to be distinctly marked at about 170°, and was replaced by an ill defined nebulous zone possessing no reflecting power; as the temperature rose, this zone increased in width in both directions, becoming at the same time more and more transparent. After a time, the liquid was entirely converted into vapour, and the tube became quite transparent and apparently empty. As the temperature fell, the same phenomena were reproduced in the opposite order (Drion, Ann. Ch. Phys. [3] lvi. 33). Similar appearances were observed on heating ether in a sealed tube to about 190°. According to Drion, the temperature at which ether is completely vaporised, in a space nearly three times its original volume, is 190·5°. The precise temperatures observed in these experiments are, however, of no real significance, unless they are accompanied by accurate determinations of the corresponding real volumes of the liquid and vapour.

It has been similarly observed by Andrews that when liquid carbonic anhydride was gradually heated to 31°, the surface of demarcation between the liquid and gas became fainter, lost its curvature, and at last disappeared. The space was then occupied by a homogeneous fluid, which exhibited, when the pressure was suddenly diminished, or the temperature slightly lowered, a peculiar appearance of moving or flickering striæ throughout its entire mass. At temperatures above 31° no apparent liquefaction of carbonic anhydride or separation into two distinct forms of matter could be effected,

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even when a pressure of 300 or 400 atmospheres was applied. Nitrous oxide gave similar results. (Andrews, in Miller's *Chemical Physics*, ed. 1863, pp. 328, 329.)

Latent Heat of Vaporisation.—When heat is imparted to a volatile liquid, its effect is, at most temperatures, twofold. Part of it goes to increase the temperature of the liquid, and part to cause vaporisation. But when a liquid is boiling under constant pressure, however much heat is communicated to it, the whole of it is absorbed in producing the second of these effects only. Conversely, when heat is withdrawn from a saturated vapour, under a pressure which is maintained constant, the vapour is changed into a liquid, without alteration of temperature. The consumption of heat in vaporisation, without the production of a corresponding elevation of temperature, and its evolution during condensation, unaccompanied by a corresponding fall of temperature, were first observed by Black. These phenomena were described by him by saying that during the former process, a certain quantity of sensible heat became latent, and that this latent heat became sensible again during condensation. The quantity of heat that must be given to a liquid to convert it into vapour, or which must be withdrawn from a vapour to convert it into liquid, without causing change of temperature, is still spoken of as the latent heat of vaporisation.

The determination of this quantity is made by determining the specific heat of the substance for an interval of temperature within which it passes from the liquid to the vaporous state, or *vice versâ*, and is therefore in principle similar to the determination of the latent heat of fluidity (p. 77). The following table gives the number of units of heat which must be imparted to a unit of weight of various liquids at their respective boiling points, in order to convert them into vapours at the same temperatures. The letters F S in the third and sixth columns denote that the determinations were made by Favre and Silbermann (Ann. Chim. Phys. [3] xxxvii. 464–470); the letter A denotes determinations by Andrews (Chem. Soc. Qu. J. i. 27); and Rg, by Regnault.

Latent Heat of Vapours.

Substance.	Latent Heat of Vapour.	Observers.	Substance.	Latent Heat of Vapour.	Observers.
Water . . .	535·77	F S	Valeric acid . .	103·52	F S
„ . . .	535·90	A	Butyric acid . .	114·67	„
„ . . .	536·67	Rg	Acetate of ethyl .	105·80	„
Bromine . .	45·60	A	„ „ .	92·68	A
Trichloride of phosphorus	51·42	„	Acetate of methyl .	110·20	„
			Formate of ethyl .	105·30	„
Sulphide of carbon . .	86·67	„	Formate of methyl	117·10	„
			Iodide of ethyl .	46·87	„
Tetrachloride of tin	3·053	„	Iodide of methyl .	46·07	„
Alcohol . . .	208·92	F S	Oxalate of ethyl .	72·72	„
„ . . .	202·40	A	Butyrate of methyl	87·33	F S
Methylic alcohol .	263·86	F S	Ethal . . .	58·44	„
„ „ .	263·70	A	Oil of turpentine .	68·73	„
Amylic alcohol .	121·37	F S	Terebene . .	67·21	„
Ether . . .	91·11	„	Oil of lemons .	70·02	„
„ . . .	90·45	A	Hydrocarbons from amylic alcohol:		
Amylic ether . .	69·40	F S	(*a*). (B. P. 205°)	59·91	„
Acetic acid . .	101·91	„	(*b*). (B. P. 250°)	59·71	„
Formic acid . .	120·72	„			

The latent heat of vaporisation varies with the temperature at which the vapour formed; more heat is for instance required to convert a given quantity of water 50° into vapour of the same temperature than to produce the same change in water 100°. It was supposed by Watt that the latent heat of vaporisation diminished exactly at the same rate as the sensible heat increased, so that the sum of the two remained constant at all temperatures. But Regnault (*Relation des Expériences*, &c. pp. 635—728; also *Works of the Cavendish Society*, vol. i. p. 294) has shown that this is not the case. He finds that the total quantity of heat λ (expressed in heat-units) which a unit of weight of saturated aqueous vapour contains at the temperature $t°$ C exceeds the amount contained in the same weight of water at 0° by the quantity

$$\lambda = 606{\cdot}5 + 0{\cdot}305\,t.$$

If from this we subtract the quantity of heat which a unit of weight of water at contains, beyond that which is contained in the same weight of water at 0° (see Regnault's determinations of the specific heat of water at different temperatures, p. 34

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we shall obtain the latent heat L of the vapour of water at the temperature $t°$. The values of λ and L for various temperatures are given in the next table, together with the tensions expressed in millimetres and atmospheres.

Latent Heat of Water-Vapour.

Temperature.	Tension.		λ	L
	mm.	atm.		
0° C.	4·60	0·006	606·5	606·5
50	91 98	1·121	621·7	571·6
100	760·00	1·000	637·0	536·5
150	3581·23	4·712	652·2	500·7
200	11688·96	15·380	667·5	464·3
230	20926·40	27·535	676·6	441·9

The following formulæ represent in like manner the results of Regnault's determinations (Mém. Acad. Sciences, xxvi. 881) of the total heats of vaporisation of several other substances at various temperatures:

Sulphide of carbon: $\lambda = 90·0 + 0·14601\,t - 0·0004123\,t^2$.
Ether: $\lambda = 94·0 + 0·4500\,t - 0·0005555\,t^2$.
Benzene: $\lambda = 109·0 + 0·2443\,t - 0·0001315\,t^2$.
Chloroform: $\lambda = 67·0 + 0·1375\,t$.
Perchloride of carbon (CCl^4): $\lambda = 52·0 + 0·1463\,t - 0·000172\,t^2$.
Acetone: $\lambda = 140·5 + 0·3664\,t - 0·000516\,t^2$.

The following table gives the total heats of vaporisation of some additional liquids at the temperatures at which they boil under the ordinary atmospheric pressure (*ibid.* 913):

Substance.	Boiling Point.	Total Heat of Vaporisation.	Substance.	Boiling Point.	Total Heat of Vaporisation.
Alcohol . . .	78·26°	265·52	Bromine . . .	60°	50·95
Amylic alcohol . .	132	211·78	Chloride of tin .	114	46·84
Oil of lemons . .	174·80	160·49	Chloride of arsenic .	133	69·74
Oil of turpentine . .	159·15	139·15	Trichloride of phosphorus .	73·80	67·24
Petrolene . . .	. .	194·87			
Chloride of ethyl . .	12·50	97·70	Acetate of ethyl .	74	154·49
Iodide of ethyl . .	71	58·95			

Regnault finds, as the result of direct experiments (*ibid.* 903), "that the total heat of vaporisation of a liquid in a current of gas is equal to that which the same liquid absorbs when it boils in an atmosphere formed by its own vapour, and exerting an elastic force equal to that actually acquired by the vapour of the liquid in the current of gas."

Cold produced by Vaporisation. Liquefaction of Gases.—When the evaporation of a liquid is hastened by reducing the pressure upon it and continually removing the vapour which forms, or by exposing a large surface and rapidly renewing the atmosphere in contact with it, the consequent absorption of heat is such, in the case of the more volatile liquids, as to produce a very considerable fall of temperature. Water, for instance, may be frozen by placing it under the exhausted receiver of an air-pump near a vessel of strong sulphuric acid (Leslie). The rapid volatilisation of more volatile liquids produces still more striking results, and in fact constitutes the most effectual means known of producing extremely low temperatures.

By causing a rapid stream of dry air from the bellows of a glass-blowers' lamp to bubble by several tubes at once through about 200 grammes of ether, Loir and Drion (Bull. Soc. Chim. Paris, i. 184; Séance du 22 Juin, 1860) succeeded in reducing the temperature of the liquid to −34° in 4 or 5 minutes, and maintaining this temperature very nearly constant for at least 15 or 20 minutes. At this temperature considerable quantities of *cyanogen* can be condensed at the atmospheric pressure. The condensation of this gas begins under these circumstances at about −22°; by blowing gently on the surface of the condensed liquid with a common pair of bellows it is immediately caused to solidify. By similar means, *sulphurous anhydride* is easily liquefied. *Chlorine* does not condense under the common pressure at −34°, but by using liquid

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sulphurous anhydride in place of ether, a temperature of $-50°$ can be produced, and this is amply sufficient for the liquefaction of both chlorine and *ammonia*. Lastly, by evaporating liquid ammonia (which boils in the air at $-35·7°$) in an exhausted receiver over sulphuric acid, they attained the temperature of about $-87°$, at which point the ammonia solidified, and *carbonic anhydride* condensed to a liquid at the common atmospheric pressure.

An apparatus for the liquefaction of ammonia, to be used for refrigeration, has been described by Regnault (Mém. Acad. Sciences, xxvi. 609), and a very simple contrivance for the same purpose was exhibited by Carré at the International Exhibition in London in 1862. (For a description and figure of the last apparatus, see Miller's *Chemical Physics*, ed. 1863, p. 298, footnote.)

Several gases can be liquefied by increased pressure alone, without reducing their temperature below that of the atmosphere. The necessary pressure can often be attained by evolving the gas in an enclosed space (as in a sealed glass tube); under these circumstances, the elastic force continues to increase until the point of maximum tension is reached, and then liquefaction occurs. In this way, carbonic anhydride may be liquefied by its own pressure when it is evolved from acid carbonate of sodium and diluted sulphuric acid in a strong wrought iron bottle connected with a wrought iron receiver. When the liquid carbonic anhydride thus produced is allowed to escape in a fine stream into the air, part of it is immediately vaporised, and the consequent absorption of heat is sufficient to cause the remainder to condense to a white, crystalline solid, like snow. The principle of this method was first put in practice by Faraday in experiments on the small scale; an apparatus in which considerable quantities of liquid carbonic anhydride could be thus prepared was first devised and constructed by Thilorier.

The pressure necessary for the liquefaction of gases may also be produced by compressing them by means of a force-pump, as in Natterer's apparatus for the liquefaction of nitrous oxide.

By the evaporation of gases, condensed by any of the processes above indicated, the lowest temperatures yet attained can be produced, the greatest degree of cold hitherto recorded being $-140°$, the temperature, according to Natterer, of a mixture of liquid nitrous oxide and bisulphide of carbon evaporating *in vacuo*.

Still more powerful means of liquefaction than those already mentioned, were employed by Faraday in his later experiments on this subject (Phil. Trans. 1845, p. 170), and he thereby succeeded in reducing to the liquid state all known gases, with the exception of oxygen, hydrogen, nitrogen, nitric oxide, carbonic oxide, and marsh-gas, —and in solidifying the greater number of them. The method adopted was to subject the gases to the joint action of powerful mechanical pressure and extreme cold. The first object was attained by the successive action of two air-pumps, the first having a piston one inch in diameter, the second only half an inch. The first produced a pressure of about 20 atmospheres, the second increased it to upwards of 50. The tubes into which the gas thus condensed was made to pass were of green bottle-glass, from $\frac{1}{8}$ to $\frac{1}{4}$ of an inch in external diameter, and had a curvature in one portion of their length adapted for immersion in a freezing mixture. The mixture employed consisted of solid carbonic anhydride and ether. The cold produced by it amounted to $-76·6°$ in the open air, and to $-110°$ under the exhausted receiver of the air-pump.

Many gases, when subjected to this extreme degree of cold, were liquefied without the use of the condensing apparatus: this was the case with chlorine, cyanogen, ammonia, sulphuretted hydrogen, arseniuretted hydrogen, hydriodic acid, hydrobromic acid, carbonic anhydride, ethylene, nitrous oxide, and oxide of chlorine. Fluoride of silicon liquefied at a pressure of 9 atmospheres. The following were solidified when subjected to the action of the carbonic anhydride bath *in vacuo:* hydriodic acid, hydrobromic acid, sulphurous anhydride, sulphuretted hydrogen, carbonic anhydride, oxide of chlorine, cyanogen, ammonia, and nitrous oxide. The following gases did not solidify, even at the lowest temperature that could be obtained: ethylene, fluoride of silicon, fluoride of boron, phosphoretted hydrogen, hydrochloric acid, and arseniuretted hydrogen. The six gases mentioned at the commencement of the preceding paragraph showed no signs of liquefaction when cooled by the carbonic anhydride bath *in vacuo:* hydrogen and oxygen at 27 atmospheres, nitrogen and nitric oxide at 50, carbonic oxide at 40, and marsh-gas at 32 atmospheres.

Andrews has since succeeded in exposing these gases to still greater pressures, but without producing liquefaction, although a bath of ether and solid carbonic anhydride was used; air was reduced to $\frac{1}{675}$ of its bulk, oxygen to $\frac{1}{554}$, hydrogen to $\frac{1}{506}$, carbonic oxide to $\frac{1}{278}$, and nitric oxide to $\frac{1}{680}$ of its original volume. Hydrogen and carbonic oxide departed less from Boyle's law than oxygen and nitric oxide.

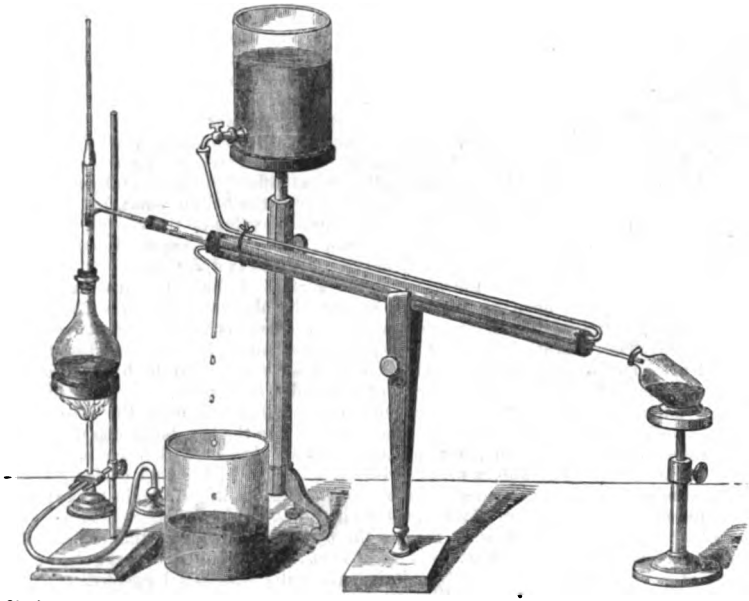
Distillation. — One of the processes most frequently resorted to by the chemist for the purpose of separating different substances is to expose the mixture containing

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them to a temperature at which the constituent it is wished to isolate rises in vapour, while the others remain still solid or liquid. The ordinary methods of performing this operation of distillation, and the apparatus commonly employed are too familiar to every chemist for it to be necessary to describe them here in detail. (For a full description of the process and the modifications that become desirable in particular cases, the reader is referred to *A Handbook of Chemical Manipulation*, by C. Greville Williams, London, 1857, pp. 202–244.)

When the liquid submitted to distillation is a mixture of two or more substances of unequal volatility, the vapour formed when ebullition begins generally contains a larger percentage of the most volatile constituent than the liquid remaining in the retort. Hence, the composition of the liquid alters as the distillation continues, and its boiling point rises accordingly. On the other hand, if the boiling point of a liquid remains constant during distillation, it is usually an indication that its composition is unaltered by the process, and therefore that the composition of the distillate also continues the same throughout. The boiling point of a liquid becomes therefore a very useful indication of the uniform or varying nature of the products of its distillation, and by collecting apart the portions which pass over at different temperatures, a mixture of different liquids may often be to a great extent resolved into its constituents. It seldom happens, however, except with a mixture of two liquids whose boiling points are very distant from each other, that a single operation of this kind gives either constituent in a state of purity. This is especially the case when the distillation is performed in a retort or other vessel which allows the vapour to pass to the condenser almost immediately after its formation. Under these circumstances, the distillate obtained at any period of the operation is almost identical in composition with the vapour that is rising from the liquid, and therefore contains a certain quantity of every constituent of the liquid that produces vapour of sensible tension at the temperature at which ebullition is going on. Hence, in order to effect any great amount of separation in this manner, the distillate must be collected in separate fractions, each of them corresponding to a definite interval of temperature; each fraction must then be fractionally distilled by itself, in the same way as the original liquid, the products which pass over between the same temperatures on the second distillation of the first fractions being collected together; and this process must be repeated as long as any further separation into

Fig. 545.



distinct constituents can be effected. These numerous re-distillations may often be considerably curtailed by using, instead of a retort, a flask fitted with a rather wide branched tube, of the form shown in *fig.* 545. The thermometer is inserted into the upright limb of the branched tube, and is so adjusted in the cork or piece of india-rubber tube which holds it in its place, that the top of the bulb is just below the opening of

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the side branch by which the vapour passes to the condenser. In an apparatus t
arranged, the vapour rising from the liquid comes in contact with a considerable surf
of glass cooled by contact with the air, before it is able to leave the distilling vessel:
consequence is that, in proportion as it rises above the surface of the boiling liquid
becomes more and more completely freed from its less volatile constituents; and the
pour which ultimately reaches the condenser, at any stage of the operation, is identi
with the most volatile portions that would be obtained by the repeated fractional dis
lation of the liquid resulting from the complete condensation of the vapour existing in
flask at the time. In fact, one distillation made in this way is equivalent to several m
in a retort; nevertheless, this method is not always applicable, since the temperature
the boiling liquid requires to be always considerably higher than that of the liquid wh
is actually distilling, otherwise the whole of the vapour would be condensed before rea
ing the exit tube—and this would sometimes cause chemical alteration of the substan

The composition of the distillate which a liquid yields at any period of its distillat
does not depend solely upon the tension of the vapours of its several constituents at
temperature of ebullition; it is greatly influenced also by their relative proportio
and by the densities of their vapours. In distilling a volatile liquid containing a sm
quantity of a less volatile one (for instance, benzene containing a little water), it m
very often be noticed that the whole of the less volatile constituent is contained in
first few drops of the distillate. This is because the latter substance produces vap
of whatever tension corresponds to the temperature of ebullition of the mass of
liquid, just as a larger quantity of it would do; this vapour diffuses itself through th
of the more volatile constituent and is carried forward with it into the condenser;
further quantity of the less volatile vapour is then formed, and the process contin
thus until the whole of the less volatile liquid has been volatilised, although the te
perature may not have approached within many degrees of its boiling point.

The influence of the vapour-densities of the several constituents of a mixed liqu
upon the rapidity with which they respectively distil, has been specially pointed out
Wanklyn (Proc. Roy. Soc. xii. 534) and by Berthelot (Compt. rend. lvii. 430). Le
ing out of consideration the influence of the adhesion of the ingredients for each oth
the quantity of each ingredient which distils may be found by multiplying its tensi
at the boiling point of the mixture by its vapour-density. Hence, the liquid wh
vapour has the highest tension will not necessarily distil the quickest: what the oth
liquids want in tension, they may make up by the greater density of the vapours whi
they give off. Wanklyn gives the following experiment in illustration of this effe
18 grms. of methylic alcohol—boiling point 66°, vapour-density 1·107—was mixed wi
17 grms. of iodide of ethyl—boiling point 72°, vapour-density 5·397—and the mixtu
was distilled until rather more than one-third had passed over. The distillate (14
grms.) consisted of 6·0 grms. of methylic alcohol and 8·7 grms. of iodide of eth
showing that the less volatile constituent, owing to its greater density of vapour, h
distilled most quickly. When the vapour-densities and tensions are inversely propo
tional, the mixture must distil over unchanged. This influence of vapour-density go
a great way to explain why homologous bodies are so difficult to separate by fraction
distillation. The more complex the formula the higher the boiling point, but also t
higher the vapour-density, and therefore the greater the value of the vapour. It al
explains why oils, &c. distil so readily in steam; for aqueous vapour is one of th
lightest, while oily vapours are generally heavy. (Wanklyn, *loc. cit.*)

The action of the sun upon the water at the surface of the earth causes a natur
process of distillation upon an enormous scale to be always going on. The wat
evaporated from the earth's surface rises in the atmosphere as vapour, and being afte
wards deprived of its heat of vaporisation—partly by radiation into space, and partly b
contact with mountain summits, or with the cold air existing at high elevations
returns to the earth in the various forms of dew, mist, rain, snow, hail, &c. In th
way an immense quantity of water is being continually lifted from the sea-level,
large proportion of which does not fall again directly into the sea, but, being deposite
on elevated portions of the land, becomes the inexhaustible source whence streams an
rivers are supplied. The watery vapour which reaches the higher and colder regio
of the atmosphere, is there condensed into snow. This, as it falls again towards th
earth, returns to the condition of water, if the air through which it passes is sufficientl
warm to liquefy it; but part of it reaches the earth unmelted, and that which fall
upon regions whose mean temperature is below zero, accumulates to form the enormou
masses of ice known as glaciers. Now it is universally admitted by geologists that
at an epoch by no means (geologically) remote, extensive glaciers existed where non
have been known within historic times, and that glaciers which still exist had then
very much greater extent. In order to account for the former existence of so muc
larger a quantity of ice at the surface of the earth than that which is now to be found
it has often been supposed that, at the period when this occurred, the mean tempera

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ture of the earth was considerably lower than at present. But, as Tyndall has pointed out (*Heat considered as a Mode of Motion*, pp. 192, 193), even admitting such to have been the case, the observed result would not have followed. If cold is necessary to condense the vapour of water into ice, heat is no less needed for the first production of the vapour. Hence the condition of the earth which is in reality indicated by the vast development of glaciers in former ages, is one in which the process of distillation went on more rapidly. These considerations have been recently carried further by Frankland. He has shown, by the comparison of well-established data, that the height of the line of perpetual snow above the sea-level at different parts of the earth, depends, not only upon the temperature, but also upon the amount of atmospheric precipitation which takes place; and he concludes, from Tyndall's experiments on the absorption and radiation of heat by aqueous vapour (see RADIATION OF HEAT), that the condensation of the vapour contained in the atmosphere takes place chiefly by the direct radiation of its heat of vaporisation into space. If this conclusion is correct, condensation must have occurred with nearly equal readiness at all stages of the earth's history, and all that was therefore necessary to cause a greater atmospheric precipitation in past times, was a more rapid supply of aqueous vapour. Hence, according to Frankland, the glacial epoch of the geologists is an indication of a higher mean temperature of the earth's surface in former ages, and not of a lower temperature. The climatological conditions of this epoch he considers to have been a necessary consequence of the continuous cooling of the earth's crust from the high temperature which it is admitted to have had at a still earlier era to that which it has at present. In the earlier ages alluded to, the temperature of the earth is supposed to have been such that a great part of the waters of our present ocean must have existed as vapour; and notwithstanding that rapid condensation of this vapour must have occurred, the surface of the earth was too hot to allow the precipitated water to accumulate as ice. But as the cooling progressed, the temperature of the land would fall more quickly than that of the ocean; hence a period would arrive when the former would be so far cooled that ice could accumulate upon it, while the temperature of the water still remained such that evaporation, and consequently condensation, went on much more rapidly than at present. It is during this period that, according to Frankland, the glacial epoch occurred. Its cessation he attributes to the further action of the same cause as that which produced it; namely, to the progressive cooling of the earth, which has now arrived at such a point that evaporation no longer takes place with sufficient rapidity to supply the materials required for the formation of the enormous glaciers of former ages. It is impossible to discuss here the cause of the former high temperature of the earth's surface, indicated by the tropical fauna and flora which preceded the glacial epoch, and, according to Frankland, by the glacial epoch itself; but it has been proved by Thomson that, for ages long anterior to either of the periods referred to, the internal heat of the earth can have produced no sensible effect upon the climate of the surface.

Just as in the process of distillation, as carried on in the laboratory, there is a transference of heat from the retort to the condenser, and consequently a constant tendency to the approximation of their temperatures: so one of the effects of the great natural process of distillation is the partial equalisation of the temperature of different parts of the earth's surface, and of the different strata of the atmosphere.

Various instruments and processes, mostly depending on principles already explained in this article, have been proposed for measuring the quantity of aqueous vapour existing in the air at any given time. A full description of all the most important of them will be found in the article HYGROMETER.

SUBLIMATION.—When, during the distillation of a volatile substance, the temperature of the receiver is kept so low that the vapour which enters it passes at once into the solid state, without previous liquefaction, the process is called sublimation, and the product a sublimate. This process is often resorted to for the purification of substances which volatilise rapidly at temperatures below their melting points.

Changes of Physical Structure.—Some solid substances are capable of existing under two or more forms distinguished from each other by differences of specific gravity, hardness, crystalline form, fusibility, optical and electrical properties, &c. Carbon, for instance, exists as diamond, graphite, and charcoal, as well as in other secondary modifications; phosphorus occurs either as an easily fusible, translucent, yellowish, crystalline substance, or as a much less fusible, opaque, amorphous body of a brick-red colour; and so for many other substances, simple and compound. It thus often happens that the different modifications of the same substance differ more in their physical properties, than other substances do which are chemically distinct; and the passage from one modification to another, though not amounting to a change of state of aggregation, may be considered as a phenomenon of the same class as such changes. Accordingly, it has been found, in all cases in which this point has been investigated, that the passage of a solid body from one modification to another, is attended either

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with development or with absorption of heat. The experiments which have been ma on this subject are not numerous enough to enable any general conclusions to be dra from them with great certainty, but they appear to indicate that development of he usually attends the passage from a vitreous or amorphous condition to a crystalli condition, and consequently that the opposite change is accompanied by absorption of hea

The following are examples of transformations of the kind under consideration :- 1. If melted sugar be allowed to cool to about 38°, and then, while it is still soft a viscid, be rapidly and frequently extended and doubled up, till at last it consists threads, as in drawn sugar, the temperature of the mass quickly rises so as to becom insupportable to the hand. After this liberation of heat, the sugar on again coolin is no longer a glass, but consists of minute crystalline grains and has a pearly lustr The same change may occur in a gradual manner, as when a clear stick of barley-sug becomes white and opaque in the atmosphere (Graham, *Elements of Chemistry*, 2n ed. i. 45).—2. When the soft vitreous sulphur, obtained by pouring sulphur melted 180° or 200° into cold water, is gradually heated in an air-bath of which the temper ture is about 98°, the temperature of the sulphur, as soon as it reaches 93°, ris suddenly to 110°, and it then passes immediately into the hard crystalline state whic it would have assumed gradually at the ordinary temperature (Regnault, Ann. C Phys. [3] i. 205). The prismatic crystals of sulphur obtained by fusion have bee long known to pass gradually into octahedral crystals. The same change takes pla much more quickly when the crystals are agitated, or when they are put in conta with sulphide of carbon, even if this liquid is already saturated with sulphu Mitscherlich found that the rapid transformation of prismatic into octahedral su phur which occurs under these circumstances was attended by the evolution of quantity of heat sufficient to raise the temperature of the sulphur employed by 12°, which, taking into account the specific heat of sulphur, amounted to 2·27 units of hea per gramme of sulphur (*ibid.* xlvi. 124). Favre, who has estimated by an indire process (Jahresber. 1853, p. 29) the heat evolved in the transformation of one variet of sulphur into another, finds that the quantity of heat liberated, when one equivalen (16 parts) of ordinary sulphur is converted into the modification insoluble in sulphid of carbon, amounts to 3102 units, and that the conversion into the same modificatio of one equivalent of soft vitreous sulphur, evolves 3804 units of heat.—3. Seleniun when completely melted and then rapidly cooled, constitutes a black mass with brilliant surface and a fracture exactly resembling that of obsidian or of black glas When this is heated very gradually, a sudden rise of temperature to 200° or 230° take place as soon as the thermometer arrives at 96° or 97°. The selenium is afterwards a bluish grey colour, and has a distinctly metallic lustre. Its fracture, instead of bein vitreous, now shows a fine granular structure like that of grey cast iron. The hea evolved in the transformation is estimated by Regnault as sufficient to raise the tem perature of the selenium operated upon by more than 200 degrees (Ann. Ch. Phys [3] xlvi. 290).—4. According to Favre (*loc. cit.*), 28,246 units of heat are evolved whe one equivalent (31 parts) of common phosphorus is converted into red phosphorus.— 5. The transformation of 1 grm. of arragonite into calc-spar corresponds to the evolutio of 12·9 units of heat (Favre and Silbermann, Ann. Ch. Phys. [3] xxxvii. 435).— 6. Many amorphous minerals and artificially prepared metallic oxides become tem porarily incandescent when gently heated, and are then found to have become crystallin without having undergone any alteration in weight. Gadolinite (silicate of yttrium exhibits this behaviour in a remarkable degree. (For further examples of analogou changes, see Gmelin's *Handbook*, i. 104–107.)

The existence of ozone seems to prove that the same chemical substance may exis even in the gaseous state, in more than one modification, and analogy renders it pro bable that, when such is the case, the transformation of one modification into the othe is attended by calorimetric phenomena. Sulphur-vapour at temperatures only slightl above the boiling point of sulphur, and at 800° and upwards, is an instance of anothe kind of difference in the properties of one and the same gaseous substance, which un doubtedly depends on the quantity of heat present in it, although the heat needed t change the one modification into the other has not been measured.

4.—*Relations of Heat to Chemical Affinity.*

Whatever may be the real nature of that property of matter called chemica affinity, by virtue of which mutual alterations of composition occur when chemically dissimilar bodies are brought together under appropriate conditions, one most im portant fact is clearly established with regard to it; namely, that its manifestation are always accompanied by the production or annihilation of heat. Change of compo sition, or chemical action, and heat are mutually convertible: a given amount o chemical action will give rise to a certain definite amount of heat, which quantity o heat must be directly or indirectly expended, in order to reverse or undo the chemical

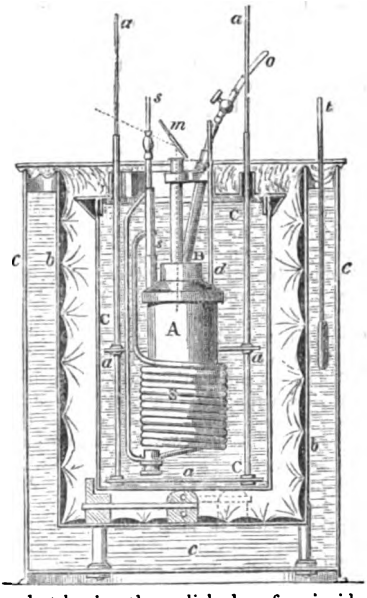
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action that has produced it. The production of heat by chemical action, and the definite quantitative relation between the amount of heat evolved and the quantity of chemical action which takes place, are roughly indicated by the facts of our most familiar experience; thus, for instance, the only practically important method of producing heat artificially consists in changing the elements of wood and coal, together with atmospheric oxygen, into carbonic anhydride and water, and every one knows that the heat which can be thus obtained from a given quantity of coal is limited and is at least approximately always the same.

The accurate measurement of the quantity of heat produced by a given amount of chemical action is a problem of very great difficulty; chiefly because chemical changes very seldom take place alone, but are almost always accompanied by physical changes involving further calorimetric effects, each of which requires to be accurately measured and allowed for, before the effect due to the chemical action can be rightly estimated. Thus the ultimate result comes, in most cases, to be deduced from a great number of independent measurements, each of which is liable to a certain amount of error. It is therefore not surprising that the results of various experiments should differ to a comparatively great extent, and that some uncertainty should still exist as to the exact quantity of heat corresponding to even the simplest cases of chemical action.

Heat evolved in rapid Combustions.—The reactions in which the evolution of heat is most strikingly evident, are of course those which are accompanied by visible incandescence or combustion; and, accordingly, the earliest experiments on the heat of chemical action had reference solely to the heat disengaged in rapid combustions. Lavoisier and Laplace were the first investigators of this subject. Their experiments, made about 1780, consisted in ascertaining the quantity of ice which could be melted by burning in a current of air known weights of the substances examined. In 1814, Count Rumford made experiments of a similar kind by means of a water-calorimeter. His chief object was to ascertain the relative calorific values of the principal combustible substances in actual use as fuel, and from this point of view his results still possess considerable value, although they cannot lay claim to scientific accuracy. In order to counteract the influence of the air and other external objects upon the temperature of his calorimeter, or at least to reduce that influence to a minimum, Rumford began each experiment when the water of the calorimeter was as much colder than the surrounding air, as (he had found by preliminary trials) it would be hotter at the end of the experiment. In this way, the calorimeter gained heat from the air during the first half of each operation, and lost an almost exactly equal quantity during the second half, so that the total effect was almost nothing. This artifice, employed for the first time by Rumford, has been adopted in nearly every subsequent investigation relating to calorimetry. The experiments of Rumford were followed by those of Crawford, Dalton, and Clement Desormes, and more recently by the investigations of Despretz and Dulong. The researches of the last named physicist were left unfinished at his death, but the results obtained appear to have been much more accurate than those of his predecessors. The most exact and comprehensive researches hitherto made into this subject are, however, those of Favre and Silbermann (Ann. Ch. Phys. [3] xxxiv. 357; xxxvi. 5; xxxvii. 406), and Andrews (Phil. Mag. [3] xxxii. 321 and 426).

Fig. 516.



The calorimeter employed by Favre and Silbermann in their experiments on combustion in oxygen gas, and in other actions whereby large quantities of heat were generated, is represented in section in *fig.* 516, the scale of which is one-fifth of that of the actual apparatus. The calorimeter, properly so called, is the cylindrical vessel CCC, made of copper plated externally with silver and brightly polished, and closed by a cover of the same material. This is surrounded by a second vessel, *b b*, also of silvered copper, but having the polished surface inside, the space between C and *b* being filled with swan's down; outside this again is a third

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vessel, *ccc*, to the bottom of which *b* is firmly connected by screw-bolts. The annul space which separates this vessel from *b* contains water, the temperature of which indicated by the thermometer *t*, and which serves to neutralise the effect of accident variations of the temperature of the atmosphere. The chamber in which the combu tions take place is made of gilt copper-plate, and is represented by A. When t combustions are to be made in oxygen, the gas, previously purified, enters this chamb by the tube *d*; the products of combustion escape, if gaseous, by the vertical tube *s*, a pass from thence into the serpentine S, where they give up their heat to the water the calorimeter, and then finally leave the apparatus by the upper part of the tube when no gaseous products are formed, the extremity of this tube is closed. If t substance to be burned is a gas, it enters the combustion-chamber by a jet connect with the tube *o*; solid bodies are attached to fine platinum-wires, suspended from t cover B, which closes the combustion-chamber; liquids are burned in small capsul or in lamps with asbestos wicks; charcoal is placed in a sort of sieve, through t openings of which the oxygen has access to it. The progress of the combustion can watched in the mirror *m* through a window in the tube below composed of a triple di of glass, alum, and quartz. The temperature of the water in the calorimeter is ke uniform throughout by means of the agitator *aaa*, which is moved by special mechanis In all cases where it was practicable to do so, Favre and Silbermann deduced t quantity of substance burned from the weight of the products of combustion.

The apparatus employed by Andrews was of much simpler construction. When t substances to be combined were in the gaseous state, and the products of combusti were also gaseous, the two gases were mixed in the proper proportions, as in a eudiom tric experiment, and introduced into a vessel of thin sheet copper, of about 24 cub inches capacity. This vessel was closed by a screw, through which passed a silver wi insulated from it by a cork, and connected by a thin platinum wire within the vess to a second silver wire soldered to the screw itself. By passing a voltaic curre through the platinum wire for an instant, it could be heated to redness and the gaseo mixture exploded. The copper vessel was introduced into a larger vessel, which w filled up with water: this was suspended in a cylinder provided with a movable cove and the whole was enclosed in an outer cylindrical vessel, arranged so as to admit its being made to rotate upon its shorter axis. The apparatus having been mounte was caused to rotate, so as to bring every part to a uniform initial temperature, whi was carefully read off by a very sensitive thermometer. The thermometer was the withdrawn; the gases exploded; the outer vessel of water closed by a cork; and th apparatus caused to rotate for thirty-five seconds. The thermometer was then agai introduced and the rise of temperature ascertained; after which the apparatus wa made to rotate a third time for thirty-five seconds, and the temperature again observe in order to ascertain the cooling effect of the atmosphere upon the apparatus durin the time that the experiment lasted: it was found that this effect seldom exceeded $\frac{1}{4}$ of the total quantity to be measured.

When solid bodies were burned in oxygen, the combustion was effected in a copp vessel, of about 250 cubic inches in capacity, which was filled with oxygen; a know weight of the combustible was placed in a small platinum dish, and when all was ready it was fired by means of a voltaic current sent through a very fine platinum wire. Th vessel in which the combustions took place was immersed in a large cylinder containin a known quantity of water, and surrounded by an outer vessel of tin-plate, to prever radiation. The copper vessel could be moved up and down in the water by means of lever. Particular expedients were sometimes required to insure ignition: thus, i burning zinc-filings and other metals in oxygen, a small fragment of phosphorus (fro 1 to 8 milligrammes) was employed to kindle the metal; the weight of the phosphoru being known, the heat evolved by it could be calculated and deducted from the tota amount produced. Some of these experiments lasted a quarter of an hour and upwards so that the correction for the cooling effect of the air became of considerable importance

When the combustions were made in chlorine, the substance to be burned was en closed in a thin glass bulb, which was broken by agitation after being immersed in th gas; in these experiments it was not necessary to apply heat to cause the combustio to begin. The chlorine itself was usually contained in a glass vessel, filled with it b displacement; in the experiments on potassium, a brass vessel was used, perfectly dr chlorine having no action on brass. An excess of the metal was always used, so as t insure the complete absorption of the chlorine, and the quantity of the latter substanc consumed was, in most cases, ascertained by weighing the quantity of water whic rushed into the vessel after the experiment on opening it under water.

The following table gives the quantities of heat, expressed in heat-units (gramme degrees), evolved in the combustion of various elementary substances in oxygen, referre (1) to 1 grm. of each element burned, (2) to 1 grm. of oxygen consumed, (3) to 1 atom (expressed in grms.) of the several elements.

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Heat of Combustion of Elementary Substances in Oxygen.

Substance.	Product.	Units of heat evolved			Observer.
		by 1 grm. of substance.	by 1 grm. of oxygen.	by 1 at. of substance.	
Hydrogen . .	H^2O	{33881 34462	4235 4308	33881 34462	Andrews. Favre & Silbermann.
Carbon:					
Wood-charcoal .	CO^2	{7900 8080	2962 3030	94800 96960	Andrews. Favre & Silbermann.
Gas-retort carbon	,,	8047	3018	96564	,,
Native graphite .	,,	7797	2924	93564	,,
Artificial graphite	,,	7762	2911	93144	,,
Diamond . .	,,	7770	2914	93940	,,
Sulphur:					
Native . .	SO^2	2220	2220	71040	,,
Recently melted .	,,	2260	2260	72320	,,
Flowers . .	,,	2307	2307	73821	Andrews.
Phosphorus:					
(yellow) . .	P^2O^5	5747	4464	178157	,,
Zinc . . .	ZnO	1330	5390	86450	,,
Iron . . .	Fe^3O^4	1582	4153	88592	,,
Tin . . .	SnO^2	1147	4230	135360	,,
Copper . . .	CuO	603	2394	38304	,,

NOTE.—Andrews' determinations have been recalculated from the original experimental numbers, using the atomic weights and specific gravities of gases adopted in this Dictionary, and therefore the numbers in the above table do not always agree precisely with those contained in the general table of results which he has himself given (Phil. Mag. [3] xxxii. 482).

The following results have been obtained by the complete combustion of partially oxidised substances:

Substance.	Product.	Units of heat evolved		Observer.
		by 1 grm. of substance.	in formation of 1 molecule of the ultimate product.	
Carbonic oxide .	CO^2	{2403 2431	67284 68064	Favre & Silbermann. Andrews.
Stannous oxide .	SnO^2	519	69584	,,
Cuprous oxide .	CuO	256	18304	,,

The substances enumerated in this table contain exactly half as much oxygen as the completely oxidised products, and on comparing the amount of heat evolved in the formation of one molecule of stannic or cupric oxide from the corresponding lower oxide, with the quantity produced when a molecule of the same product is formed by the complete oxidation of the metal in one operation (see previous table), we find that the combination of the second half of the oxygen contained in these bodies evolves sensibly half as much as the combination of the whole quantity. In the formation of carbonic anhydride, however, the second half of the oxygen appears to develope more than two-thirds of the total amount of heat; but this result is probably due, in part at least, to the fact that when carbon is burned into carbonic anhydride, a considerable but unknown quantity of heat is expended in converting the solid carbon into gas, and thus escapes measurement; while, in carbonic oxide, the carbon already exists in the gaseous form, and therefore no portion of the heat evolved in the combustion of this substance, is similarly expended in producing a change of state.

It seems probable also, that a similar explanation may be given of the inequalities in the quantities of heat produced by the combustion of different varieties of pure carbon and of sulphur,—that is to say, that a portion of the heat generated by the combustion of diamond and graphite goes to assimilate their molecular condition to that of wood-charcoal, and that there is an analogous expenditure of heat in the combustion of native sulphur: indeed, with regard to the latter case, it is proved by direct experiments (see p. 102), that the opposite change to that supposed to take place here of recently melted sulphur into the same molecular condition as native sulphur is accompanied by disengagement of heat.

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In like manner, the heat evolved in combustions may in some cases be in excess of that due to the strictly chemical action which takes place: thus, when the product of combustion is solid, part of the heat must be ascribed to the solidification of the oxygen absorbed. Again, the heat of combustion of hydrogen, as given above, includes the latent heat of vaporisation of the water formed. In Andrews' experiments the temperature of the calorimeter was about 20° C.: at this temperature the latent heat of vaporisation of 9 grms. of water (the quantity formed from 1 grm. or atom of hydrogen) may be taken as = 5500; and deducting this quantity from 33,881, we have 28,381 as the number of units of heat evolved by the chemical combination of 1 grm. hydrogen and 8 grms. oxygen, according to these experiments. Favre and Silbermann do not give the temperature of their calorimeter, but probably the same correction may be applied to their experiments without much error: they then give 34,462—5500 = 28,962 as the true heat of combustion of 1 grm. of hydrogen.

The experiments which have been made on the heat of combustion of definite compounds, other than the three already mentioned, relate almost exclusively to bodies composed of carbon and hydrogen, or of carbon, hydrogen, and oxygen. The results obtained by Favre and Silbermann and Andrews are contained in the following table. The numbers here given represent the total heat produced, and therefore include that due to the condensation of the vapour of water formed in the experiments.

Many of these numbers must be regarded as approximations only (and sometimes as not very close approximations) to the truth. The chief causes of uncertainty with regard to them, besides the difficulties inherent in the experimental determinations themselves, are the different calorimetric properties of the substances examined—differences, that is, in regard to specific and latent heats—and, in some cases, their admittedly doubtful purity. Hence it is impossible to trace any exact correspondence between the composition of the bodies experimented upon, and the amount of heat which they evolve upon combustion. A few general conclusions are, however, indicated with sufficient clearness to make it worth while to dwell upon them briefly.

In the first place it appears that the heat of combustion of a compound is in general less than the heat of combustion of its elements. This rule is verified in the case of all the hydrocarbons given in the table, with the exception of olefiant gas, whose heat of combustion is almost exactly the same as that of its constituents, according to Favre and Silbermann's determinations, and somewhat greater, according to Andrews. When a hydrocarbon is burned into carbonic anhydride and water, the chemical change which takes place consists, not merely in the union of carbon and hydrogen with oxygen, but also in their separation from their previous state of combination with each other. Now, it is an almost self-evident proposition, and one which has moreover received direct experimental confirmation, that whatever may be the calorimetric effect of any given chemical change, the calorimetric effect of its reversal is equal and opposite. Hence, if we suppose the combination of carbon and hydrogen—to form marsh-gas, for example—to be accompanied by evolution of heat, we must suppose that their separation is attended by the disappearance of an equal quantity of heat. The heat produced by the combustion of one molecule of marsh-gas, CH^4, is therefore less than the quantity due to the combustion of one atom of (gaseous) carbon and four atoms of hydrogen, by the quantity of heat absorbed when these atoms separate from combination with each other. Assuming (for want of more certain data) that the heat of combustion of an atom of gaseous carbon is twice that of a molecule of carbonic oxide, we have, for the heat of combustion of $C + H^4$ (in round numbers), $134,600 + (4 \times 34,460) = 272,440$; but the heat of combustion of CH^4 is 209,000, which gives $272,440 - 209,000 = 63,440$ as the number of units of heat produced by the combination of 1 atom of carbon with 4 atoms of hydrogen, or absorbed when these atoms separate. In like manner, we have, for the heat of combustion of $C^2 + H^4$, $(2 \times 134,600) + (4 \times 34,460) = 407,040$ units; and deducting from this the heat of combustion of olefiant gas, we have $407,000 - 332,000 = 75,000$ for the calorimetric effect due to the separation of the atoms of a molecule of olefiant gas from each other. The difference between 63,400 (the heat of formation of CH^4) and 75,000 (the heat of formation of C^2H^4), namely 11,600, may perhaps be taken as representing the calorimetric effect of the combination or separation of the two atoms of carbon contained in olefiant gas. The fact that the heat of combustion of olefiant gas, as found by direct experiment, is very nearly equal to the sum of the heats of its constituents, when the heat of an atom of carbon is taken at 96,960 units, the quantity deduced from the combustion of wood-charcoal, probably indicates that the heat of vaporisation required to change the physical condition of two atoms of carbon from that of wood-charcoal to that which it has in the form of olefiant gas, is nearly the same as the heat required to separate the atoms of a molecule of olefiant gas from each other. That the heat of vaporisation of carbon is very considerable is further indicated by the great difference, already alluded to, between the caloric effect of the first and second atoms of oxygen contained in carbonic anhydride,

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Heat of Combustion of Compounds in Oxygen.

Substance.	Formula.	Molecular weight.	Units of heat evolved. by 1 grm. of substance.	Units of heat evolved. by 1 molecule of substance.	Observer.
Marsh-gas	CH^4	16	13108	209728	Andrews.
			13063	209008	Favre and Silbermann.
Olefiant gas	C^2H^4	28	11942	334376	Andrews.
			11853	332024	Favre and Silbermann.
Amylene	C^5H^{10}	70	11491	804370	,,
Paramylene	$C^{10}H^{20}$	140	11303	1582420	,,
Hydrocarbon: (from amylic alcohol boiling point 180°)	$C^{11}H^{22}$	154	11262	1734348	,,
Cetylene	$C^{16}H^{32}$	224	11055	2476328	,,
Metamylene	$C^{20}H^{40}$	280	10928	3059840	,,
Oil of lemons	$C^{10}H^{16}$	136	10959	1490424	,,
Oil of turpentine	$C^{10}H^{16}$	136	10852	1475872	,,
Terebene	$C^{10}H^{16}$	136	10662	1450032	,,
Ether	$C^4H^{10}O$	74	9028	668072	,,
Amylic ether (impure?)	$C^{10}H^{22}O$	158	10188	1609704	,,
Methylic alcohol	CH^4O	32	5307	169824	,,
Ethylic alcohol	C^2H^6O	46	7184	330464	,,
			6850	315100	Andrews.
Amylic alcohol	$C^5H^{12}O$	88	8959	788392	Favre and Silbermann.
Cetylic alcohol: (latent heat of fusion added)	$C^{16}H^{34}O$	242	10629	2572218	,,
Formic acid	CH^2O^2	46	2091	96186	,,
Acetic acid	$C^2H^4O^2$	60	3505	210300	,,
Butyric acid	$C^4H^8O^2$	88	5647	496936	,,
Valeric acid	$C^5H^{10}O^2$	102	6439	656778	,,
Palmitic acid	$C^{16}H^{32}O^2$	256	9316	2384896	,,
Stearic acid	$C^{18}H^{36}O^2$	284	9716	2759344	,,
Formate of methyl	$C^2H^4O^2$	60	4197	251820	,,
Acetate of methyl	$C^3H^6O^2$	74	5342	395308	,,
Formate of ethyl	$C^3H^6O^2$	74	5279	390646	,,
Acetate of ethyl	$C^4H^8O^2$	88	6293	553784	,,
Butyrate of methyl	$C^5H^{10}O^2$	102	6798	693447	,,
Butyrate of ethyl	$C^6H^{12}O^2$	116	7091	822556	,,
Valerate of methyl	$C^6H^{12}O^2$	116	7376	855616	,,
Valerate of ethyl	$C^7H^{14}O^2$	130	7835	1018550	,,
Acetate of amyl	$C^7H^{14}O^2$	130	7971	1036230	,,
Valerate of amyl	$C^{10}H^{20}O^2$	172	8544	1469568	,,
Palmitate of cetyl (spermaceti)	$C^{32}H^{64}O^2$	480	10342	4964160	,,
Hydrate of phenyl	C^6H^6O	94	7842	737148	,,
Sulphide of carbon	CS^2	76	3400	258400	,,

as well as by the fact that the heat of combustion of a molecule of sulphide of carbon exceeds the sum of the heats of its constituents.

It will be understood that the foregoing calculations are given, rather for the sake of drawing attention to the necessity of taking account of *all* the changes, whether

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chemical or physical, which accompany a given chemical reaction, when we are cussing the quantity of heat produced by it, than because the results arrived at supposed to be numerically accurate. Indeed it is by no means probable that t results are, at best, anything more than roughly approximative; for, to mention other source of uncertainty, the assumption that we have made, that the heat produ by the complete combustion of carbon is twice as great as that evolved by the com tion of the same quantity of carbon in the form of carbonic oxide, is most likely strictly true. For it has been pointed out by Butlerow that the four unit combining capacity (CLASSIFICATION, i. 1010 *et seq.*) possessed by one atom of car are not exactly equivalent to each other in chemical function, and Erlenmeyer suggested, with great probability, that the difference between them is due to differe in the strength of the chemical affinity with which each unit enters into combina (see references in the article FORMULÆ, ii. 704). If this be so, the combinatio an atom of carbon with one atom of oxygen must evolve more heat than the combina of the product so formed (carbonic oxide) with a second atom of oxygen.

The numbers in the above table show that the heat evolved by the combustio equal weights of the hydrocarbons $(CH^2)^n$, homologous with olefiant gas, diminishe their molecular weights increase. But it is not easy to say how far this result may due to accidental causes (the numbers given are deduced from a single experim except in the case of olefiant gas, for which Favre and Silbermann obtained very c cordant results in two experiments), or to the influence of the physical properties the substances. It may be remarked that the isomeric substances, oil of lemons, o turpentine, and terebene, also gave different quantities of heat, although th molecular weights are the same.*

The acids homologous with acetic acid may be regarded, empirically, as for by the combination of the hydrocarbons $(CH^2)^n$ with oxygen; that is, they may considered as products of the partial combustion of the hydrocarbons. Hence, should expect each acid to give out, when burned, less heat than the hydrocarbon c taining the same quantity of carbon and hydrogen, and this is shown by the number the above table, to be really the case, the difference between the heat of combustio an acid and that of a given hydrocarbon being greater in proportion as the acid is m oxidised. Thus, starting from amylene, C^5H^{10}, and comparing with it quantities valeric, butyric, and acetic acids which contain the same quantity of carbon hydrogen, we have the following numbers:

1	molecule amylene,	C^5H^{10}	= 70	produces	804400	units of h
1	„	valeric acid, $C^5H^{10}O^2 = C^5H^{10} + O^2$	= 102,	„	656800	„
1½	„	butyric acid, $1\frac{1}{2}C^4H^8O^2 = C^5H^{10} + O^{2\frac{1}{2}}$	= 110,	„	621200	„
2½	„	acetic acid, $2\frac{1}{2}C^2H^4O^2 = C^5H^{10} + O^5$	= 150,	„	525750	„

Compared in this way, the difference in composition between amylene and val acid, namely O^2, is four times as great as that between valeric acid and butyric a and the corresponding differences in the heats of combustion of these substances exactly almost in the same proportion: but this close agreement is, probably, in gr part accidental: for the heat of combustion of acetic acid is decidedly greater th what might be calculated in the same way.

The table further shows that isomeric substances by no means always give out eq quantities of heat when burned. For instance, acetic acid, $C^2H^4O^2$, produces c siderably less heat than its isomer, formate of methyl; butyric acid, $C^4H^8O^2$, less than isomer, acetate of ethyl; valeric acid, $C^5H^{10}O^2$, less than its isomer, butyrate of meth That differences of this kind would be found to exist, might have been deduced, w considerable probability, from the differences in the chemical constitution of the ac and of the isomeric ethers: for, of the four equivalents of oxygen contained in th compounds, one must be regarded as combined with hydrogen, and the other three wi carbon in the acids; whereas, in the ethers, all four equivalents of oxygen are co bined with carbon. Hence, the differences between the heats of combustion of t acids $C^nH^{2n}O^2$ and those of the isomeric ethers may be ascribed, at least in part, the difference between the heat of combustion of an equivalent of carbon and that an equivalent of hydrogen; but considerations, such as have been already alluded t make it impossible to assign any exact numerical value to this difference.

But, according to the experiments hitherto made, not only do the acids differ fro the isomeric ethers, in the quantity of heat which they produce when burned, but th ethers differ from each other: for instance, acetate of methyl produces more heat tha its isomer formate of ethyl; valerate of methyl, more than its isomer butyrate ethyl; acetate of amyl, more than its isomer valerate of ethyl. It is not easy to sugge any chemical reason for the existence of such differences as these; nor even to discov any empirical relations of a general kind among the experimental results.

* Favre and Silbermann assign to oil of lemons half the molecular weight of oil of turpentine, b without giving any reason for so doing.

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[For the methods of calculating the heating powers of different kinds of fuel, and e temperature produced by its combustion, for practical purposes, see the article EL, ii. 722 *et seq.*]

Combustions in Chlorine, and direct combination of Chlorine, Bromine, and Iodine.—ie following table gives the quantities of heat evolved by the direct union of various ements with gaseous chlorine:

Substance.	Product.	Units of heat evolved			Observer.
		by 1 grm. of substance.	by 1 grm of chlorine.	by 1 at. (=35·5 grms.) of chlorine.	
Hydrogen .	HCl	{24087	678	24087	Abria.
		{23783	670	23783	Favre and Silbermann.
Phosphorus .	PCl^5(?)	3422(?)	607	21548	Andrews.
Potassium .	KCl	2655	2943	104476	,,
Iron . .	Fe^2Cl^6	1745	921	32695	,,
Zinc . .	$ZnCl^2$	1529	1427	50658	,,
Tin . .	$SnCl^4$	1079	897	31722	,,
Arsenic .	$AsCl^3$	994	704	24992	,,
Copper . .	$CuCl^2$	961	859	30494	,,
Antimony .	$SbCl^5$	707	860	30491	,,
Mercury .	?	?	822	29181	,,

The heat evolved by the direct union of bromine and iodine with zinc and iron has also been determined by Andrews (Trans. Roy. Irish Acad. xix. quoted in Miller's *Chemical Physics*, p. 341): the results obtained are given in the next table:

Metal.	Product.	Units of heat evolved		
		by 1 grm. of metal.	by 1 grm. of bromine or iodine.	by 1 at. of bromine or iodine.
		Bromine.		
Zinc . .	$ZnBr^2$	1269	508	40640
Iron . .	Fe^6Br^6	1277	298	23833
		Iodine.		
Zinc . .	ZnI^2	819	209	26617
Iron . .	Fe^2I^6	463	63	8046

Heat produced by reactions in the Wet Way.—Of the various reactions in the wet way, which have been studied calorimetrically, it will be most convenient to consider first those which take place between water and other bodies, since such actions intervene in many other cases also.

Dilution of Acids with Water.—The heat produced by the dilution of strong acids, especially sulphuric acid, has been the subject of many investigations, the most accurate of which are probably those of Favre and Silbermann, Thomsen (Pogg. Ann. lxxviii. 349; xc. 261; Jahresber. 1853, p. 30); and Favre and Quaillard (Compt. rend. l. 1150). We give below a few of the results obtained.

Sulphuric acid, SO^4H^2 = 98.

Thomsen determined the quantity of heat evolved by the mixture of strong sulphuric acid, and of the same previously diluted with different quantities of water, with an excess of water—that is, with so much that any further quantity did not increase the amount of heat evolved. He found that the addition of an excess of water

to 98 grms. (=1 molecule)	SO^4H^2	evolved	17,248	units of heats.
to 116	,, $SO^4H^2.H^2O$	,,	10,848	,,
to 152	,, $SO^4H^2.3H^2O$	,,	6288	,,
to 188	,, $SO^4H^2.5H^2O$	,,	4480	,,

Favre has determined, in conjunction with Silbermann and with Quaillard, the quantity of heat produced by the successive additions of known quantities of water to strong sulphuric acid. Both sets of experiments were made with the mercurial

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calorimeter already described, and represented in *fig.* 531, p. 28. We give her results published by Favre and Quaillard as being the most recent.

Addition of Water to 98 *grammes* (1 *molecule*) *of Sulphuric Acid.*

Quantities of water added successively. Molecules.	Heat evolved on each successive addition of water.	Total quantity of water added. Molecules.	Total Heat evolved.	Quantities of water added successively. Molecules.	Heat evolved on each successive addition of water.	Total quantity of water added. Molecules.	T
⅛	946·68			1	885·30	5	1
⅛	885·92 } 6375·88			1	754·48	6	1
¼	1711·08			1	591·84	7	1
½	2832·20			1	465·36	8	1
1	. . . 6512·80	1	6512·80	4	1063·66	12	1
½	1842·40 } 3180·50			4	483·02	16	1
½	1338·10			4	222·46	20	1
1	. . . 3244·00	2	9756·80	4	141·58	24	1
½	1009·40 } 1814·52			4	86·96	28	1
½	805·12			4	65·06	32	1
1	. . . 1840·80	3	11597·60	4	43·28	36	1
1	. . . 1179·00	4	12776·60	4	32·08	40	1

A little heat was still produced by the addition of the sixtieth molecule of water.

These numbers show that a given quantity of water added to sulphuric acid ev the same quantity of heat, whether it be added all at once, or in successive s portions, and that the heat which a given quantity of water produces is, accordi less in proportion as the amount previously added is greater.

Nitric Acid, $NO^2H = 63$.

The following table gives the results of Thomsen's experiments on the heat evo on adding an excess of water to nitric acid, either undiluted or already containi certain quantity of water. The numbers refer, as usual, to molecular proportio acid and water expressed in grammes:—

NO^2H	mixed with excess of water				evolved	7560	units of heat
(NO^2H + 0·421	H^2O)	mixed with	excess of	water	evolved	5680	,, ,,
(NO^2H +	H^2O)	,,	,,	,,	,,	4088	,, ,,
(NO^2H + 1·5	H^2O)	,,	,,	,,	,,	3760	,, ,,
(NO^2H + 1·59	H^2O)	,,	,,	,,	,,	3464	,, ,,
(NO^2H + 2	H^2O)	,,	,,	,,	,,	2712	,, ,,
(NO^2H + 2·5	H^2O)	,,	,,	,,	,,	2184	,, ,,
(NO^2H + 3·5	H^2O)	,,	,,	,	,,	1392	,, ,,
(NO^2H + 4·5	H^2O)	,,	,,	,	,,	952	,, ,,

It will be observed that the heat which can be obtained by the addition of wate nitric acid diminishes as the quantity of water already present in the acid is gre but that the diminution takes place, at first, much less rapidly than in the cas sulphuric acid.

Acetic Acid, $C^2H^4O^2 = 60$.

The following results are those of Favre and Quaillard: we give them in orde call attention to the absorption of heat (indicated by the *minus* sign in the sec column) produced by the first quantities of water added:

Quantities of water added successively.	Heat evolved on each addition of water.	Total quantity of water added.	Quantities of water added successively.	Heat evolved on each addition of water.	Total quantity of wa added.
⅛ H^2O	− 72·22 }		⅛ H^2O	+ 3·51	2 H^2O
⅛ ,,	− 33·13 } − 135·00		¼ ,,	5·97	2½ ,,
⅛ ,,	− 17·66 }		½ ,,	11·28	3 ,,
⅛ ,,	− 11·99 }		1 ,,	23·45	4 ,,
⅛ ,,	. . − 135·16	½ H^2O	1 ,,	27·47	5 ,,
¼ ,,	− 16·65 } − 24·87		2½ ,,	82·47	7½ ,,
¼ ,,	− 8·22 }		2½ ,,	54·73	10 ,,
½ ,,	. . − 25·18	H^2O	5 ,,	87·72	15 ,,
½ ,,	. . − 3·56	1½ H^2O	5 ,,	40·54	20 ,,

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These numbers plainly show the simultaneous occurrence of two distinct actions—one of them attended with absorption of heat, the other with its production. The former action prevails at first, but gradually diminishes as more and more water is added, until, on the addition of the fourth half-molecule, its effect becomes less than that of the second, and a small evolution of heat takes place. From this point, until between five and seven-and-a-half molecules of water have been added, the calorific effect of a given quantity of water continually *increases* (contrary to what takes place with sulphuric and nitric acids), showing that the heat-absorbing action still takes place, but to a less and less extent, until more than five molecules of water have been added to each molecule of acetic acid.

When successive quantities of alcohol, up to ten molecules, are added to acetic acid, each addition causes absorption of heat; but the numerical results clearly indicate, in this case also, the simultaneous occurrence of distinct phenomena. Favre obtained the following results:

Molecules of alcohol successively added to 1 molecule of acetic acid	1	1	1	1	2	2	2
Units of heat *absorbed* on the addition of each successive quantity	91·91	0·91	7·35	14·88	31·85	41·47	64·50

Absorption of heat also frequently occurs on the dilution of saline solutions, a phenomenon with regard to which numerous quantitative determinations have been made by Favre. It is probable that in these cases, a change takes place more or less analogous to the liquefaction of a solid by solution: acetic acid, or a salt dissolved in a small quantity of water, may be conceived of as being imperfectly liquefied, so that further liquefaction, accompanied by the disappearance of a certain quantity of heat, takes place on the addition of more water. Viewed in this way, these phenomena appear to be comparable with the gradual melting, which, as we have seen (pp. 74 and 76), takes place in some solids under the direct action of heat.

Reaction of Acids and Bases in presence of water.—It will be easily understood that the thermal effects which may result from the reaction of different substances upon each other in presence of water, are even more complicated than any of those which have yet been considered, and therefore that the calorimetric study of these reactions is subject to still more numerous causes of error than that of the foregoing processes. In addition to the different specific heats of the reagents and products, and to the different quantities of heat absorbed by them in dissolving, or given out by them in combining with water, the conversion of soluble substances into insoluble ones, as a consequence of the chemical action, or the inverse change of insoluble into soluble bodies, are among the secondary causes to which part of the calorimetric effect may be due in these cases. The greater number of these disturbing causes may be got rid of, or at least very much reduced in amount, by effecting the reactions in the presence of comparatively large quantities of water, but then the difficulty of accurately measuring the total quantity of heat produced becomes greater.

The following table gives the number of units of heat evolved, according to Favre

Oxide of	Equivalents.	Units of Heat evolved with Various Acids:			
		Sulphuric.	Nitric.	Hydrochloric.	Acetic.
Potassium .	47	16083	15510	15656	13978
Sodium . .	31	15810	15283	15128	13600
Ammonium .	26	14690	13676	13536	12649
Barium . .	76·5	. .	15360	15306	13262
Calcium . .	28	. .	16943	16982	14675
Magnesium .	20	14440	12840	13220	12270
Manganese .	35·5	12075	10850	11235	9982
Zinc . . .	40·5	10455	8323	8307	7720
Cadmium . .	64	10240	8116	8109	7546
Copper . .	39·7	7720	6400	6416	5264
Nickel . .	37·7	11932	10450	10412	9245
Cobalt . .	37·7	11780	9956	10374	9272
Lead. . .	111·7	. .	9240	. .	7168
Silver . .	116	. .	6206		

and Silbermann's experiments, in the transformation of equivalent quantities of various

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metallic protoxides into neutral salts, the reaction taking place in all cases in presence of a large quantity of water, and the products being all soluble.

The heat evolved by equivalent quantities of potash and soda respectively, in forming neutral salts with the following additional acids, is shown in the next table:

Acids.	Potash.	Soda.	Acids.	Potash.	Soda.
Hydrobromic acid .	15510	15159	Valeric acid . .	. .	13500
Hydriodic acid .	15698	15097	Citric acid . .	13658	13178
Metaphosphoric acid . .	16168	15407	Oxalic acid . .	14156	13752
			Tartaric acid . .	13425	12651
Pyrophosphoric acid	16920	15655	Carbonic acid .	12878	. .
Phosphoric acid .	17766	. .	Hydrosulphuric acid . .	6477	6550
Formic acid . .	. .	13308			

Numerous determinations of a similar kind have also been made by Andrews (Trans. Roy. Irish Academy, xix.; Rep. Brit. Associat. 1849, p. 69; see also Miller's *Chemical Physics*, p. 352). The following is the most important of the conclusions at which he arrived:—"An equivalent of the same base, combined with different acids, produces *nearly* the same quantity of heat; but an equivalent of the same acid combined with different bases, produces different amounts of heat." It is, however, scarcely needful to point out, that such a difference as is here implied between the chemical behaviour of acids and bases does not really exist in nature, and that its appearing to be indicated by the experiments in question, could only result from the accident of the bases examined representing a greater range of varying chemical energy than the acids.

The results obtained on bringing together an alkali and an acid in various proportions are of considerable interest. They show clearly that, at least in the case of the most distinctly characterised acids, chemical action takes place only between definite atomic proportions of acid and alkali. The numbers given below represent the number of units of heat evolved by one equivalent of potash or soda (the quantity containing 39 pts. potassium, or 23 pts. sodium) when acted on by varying quantities of acid.

1 equivalent potash
with 1 equivalent sulphuric acid gave 15609 units of heat.
„ 2 „ „ „ „ 15609 „ „
„ 1 „ acetic „ „ 13935 „ „
„ 2 „ „ „ „ 13823 „ „ (Favre and Silbermann).

The results of Thomsen's experiments (Jahresber. 1854, p. 30) with sulphuric acid and potash and soda are as follows:

Equivalents of acid		½	¾	1	1½	2	4
Heat evolved	Soda	5424	10656	15368	15320	15524	15216
	Potash	4968	9880	15368	. .	15248	

It will be seen that the evolution of heat increases sensibly in the same proportion as the quantity of acid used, up to one equivalent, but that beyond this point no further increase in the amount of heat evolved accompanies the augmentation of the quantity of acid. Hence it appears that acid sulphates of potassium and sodium are not formed in presence of a large quantity of water, a conclusion which agrees with Favre and Silbermann's observation, that the evolution of heat which takes place on adding one equivalent of base to a dilute solution of acid sulphate or sulphite of potassium, is the same as if the second equivalent of acid contained in the salt were employed in the free state. By experiments on the heat evolved on adding successive quantities of other acids—such as boric, silicic, phosphoric—to one equivalent of soda or potash, Thomsen found that the heat produced was at first nearly in proportion to the quantity of acid added, but that, as the latter was increased, the evolution of heat increased also, though in a continually slower ratio.

Evolution of Heat in the formation of Aqueous Solutions.—When a gas dissolves in water, the heat due to the chemical action is augmented by that due to the physical phenomenon of the liquefaction of the gas; so also, when a solid body is dissolved in water, the total thermal effect observed is due in part to the chemical action taking place between the water and the solid, and in part to the liquefaction of the substance dissolved. In the former case, the chemical and physical parts of the phenomenon both cause evolution of heat: in the latter case, the physical change occasions disappearance of heat; and if this effect is greater than that due to the chemical action, the ultimate result of the combined process is the production of cold, and it is this which

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most usually observed. The following tables contain the results of Favre and Silbermann's experiments, calculated for one gramme of gas or solid salt dissolved.

Solution of Gases in Water.

Name of Gas.	Units of heat evolved.	Name of Gas.	Units of heat evolved.
Hydrochloric acid . .	449·6	Sulphurous acid . .	120·4
Hydrobromic acid . .	235·6	Ammonia	514·3
Hydriodic acid . . .	147·7		

Solution of Salts in Water.

Name of Salt.	Units of heat absorbed.	Name of Salt.	Units of heat absorbed.
Sulphate of potassium .	35·3	Nitrate of sodium . .	45·5
„ sodium . .	49·1	„ ammonium .	65·9
„ ammonium .	11·1	„ calcium . .	27·1
„ calcium . .	24·7	„ strontium . .	41·2
„ barium . .	64·4	„ lead . . .	14·9
„ zinc . .	14·8	„ silver . . .	31·1
Ferrous sulphate . .	12·1	Phosphate of sodium . .	52·3
Uranic sulphate . . .	+ 10·7	Pyrophosphate of sodium .	21·9
Potassio-ferrous sulphate .	21·5	Oxalic acid . . .	67·0
Sulphate of aluminium and potassium , . .	23·1	Oxalate of potassium . .	39·7
Sulphate of aluminium and ammonium . . .	19·0	Acid oxalate of potassium .	62·1
Acid sulphate of potassium.	25·6	Tartrate of potassium .	17·3
Chloride of potassium .	51·9	„ sodium . .	25·2
„ sodium . .	8·9	Tartaric acid . . .	19·8
„ ammonium .	65·1	Tartrate of potassium and sodium	40·9
„ calcium . .	15·5	Acetate of sodium . .	28·1
„ barium . .	16·9	„ calcium . .	3·5
„ strontium . .	24·9	„ lead . . .	14·8
„ zinc (anhydrous)	+ 92·2	Acid acetate of potassium .	19·3
Ferrous chloride (anhydrous)	+ 58·3	Carbonate of sodium . .	52·7
Cupric chloride (anhydrous)	+ 73·7	Acid carbonate of potassium	51·5
Bromide of potassium .	37·8	Sulphide of potassium (anhydrous) . . .	+ 96·9
Iodide of potassium . .	29·2		
Nitrate of potassium . .	70·5		

NOTE.—The sign *plus* (+) denotes evolution of heat.

The foregoing table includes numbers relating to the solubility of some salts which are, in reality, either quite insoluble or very slightly soluble in water. These numbers are deduced from a comparison of those which represent the heat of formation of these salts with the numbers expressing the heat evolved by the same bases with other acids. The heat of formation of salts which are insoluble, and therefore separate out in the solid form, is usually considerably greater than the heat of formation of soluble salts of the same bases and acids, and it is this excess which in the above table is given as the heat absorbed on solution by such salts as sulphate of barium, sulphate of strontium, &c.

Cold produced by Chemical Decomposition.—The proposition that the thermal effect of the reversal of a given chemical action is equal and opposite to the thermal effect of that action itself, has already been referred to (p. 106) as one which might with great probability be assumed as true. A direct consequence of this proposition is that *the separation of any two bodies is attended with the absorption of a quantity of heat equal to that which is evolved in their combination.* The truth of this deduction has been experimentally established in various cases by Woods (Phil. Mag. [4] ii. 368; iv. 370); Joule (*ibid.* iii. 481) and Favre and Silbermann, by comparing the heat evolved in the electrolysis of dilute sulphuric acid, or solutions of metallic salts, with that which is developed in a thin metallic wire by a current of the same strength; and by comparison of the heat evolved in processes of combination accompanied by simultaneous decompositions, with that evolved when the same combination occurs between free elements.

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In the experiments of Woods, a voltaic current was first made to pass through a vessel containing dilute sulphuric acid, and the quantity of gas evolved in a given time was determined, and also the simultaneous rise of temperature, the strength of the current being measured at the same time by the tangent-compass (ii. 460). The electrolytic cell was then removed, and a thin platinum wire introduced between the poles, of such a length as to produce a resistance equal to that of the electrolyte. The quantity of heat evolved in this wire was then determined, and found to exceed that which was previously evolved in the electrolytic cell, by a quantity equal to that which would be evolved by the combination of the oxygen and hydrogen set free by the current in the previous experiment.

Joule made similar experiments on the decomposition of dilute sulphuric acid, sulphate of copper, and sulphate of zinc; and, regarding the difference in the quantity of heat evolved when the current traversed a circuit completely metallic, and when the metallic circuit was broken by the interposition of an electrolyte, as the heat absorbed by the separation of the elements of the electrolyte, he obtained numbers which agree very fairly with those found by other experimenters for the heat evolved in the union of the same elements, as shown in the following table, which gives the quantities of heat evolved or absorbed in the oxidation or reduction of 1 gramme of each metal, according to various experimenters.

	Joule.	Dulong.	Andrews.	Favre and Silbermann.	Grassi.	Woods.
Copper .	594	. .	600	655	. .	611
Zinc . .	1185	1297	1315	1277	. .	1307
Hydrogen .	33553	34587	33808	34462	34666	

The proposition in question has also been confirmed by experiments of another kind. Thus, for instance, by determining the heat evolved when different metals were dissolved in water or dilute acid, Woods found that it was less than that which would be produced by the direct oxidation of the same metals, by a quantity equal to that which would be obtained by burning the hydrogen set free, or which was expended in decomposing the water or acid; and therefore that, when this latter quantity was added to his results, they agreed with the numbers given by experiments of direct oxidation. The quantities of heat evolved by 1 gramme of the several metals, when augmented by that corresponding to the decomposition of the water or acid, were as follows:—

Metal.	Heat by solution of 1 gramme.	Metal.	Heat by solution of 1 gramme.
Sodium . . .	3293	Tin . . .	595
Potassium . .	1745	Lead . . .	256
Zinc . . .	1307	Mercury . .	118
Iron . . .	1204	Silver . . .	96
Copper . . .	611	Bismuth . .	95·5

Indirect methods of determining Heat of Combination.—Assuming the truth of the proposition that in the decomposition of a compound as much heat is absorbed as is liberated in its formation, it is obvious, from the foregoing examples, that the calorimetric effect of a given chemical change can be calculated if the effects of all those which occur simultaneously with it are known. Upon this principle, which is merely that adopted by Woods in the experiments described in the last paragraph, Favre and Silbermann have made a very extensive series of determinations of the quantities of heat evolved in reactions which could not have been easily investigated directly. Their experiments were made with the mercurial calorimeter, and the heat due to a given process was in some cases deduced from two distinct reactions. Thus, the heat of formation of oxide of zinc was deduced (1) from the solution of metallic zinc in dilute sulphuric acid, (2) from the solution of zinc in dilute hydrochloric acid. For the purposes of calculation, the former reaction was considered as consisting in the formation of oxide of zinc, with simultaneous decomposition of water, $Zn + H^2O = ZnO + H^2$, and in the subsequent formation of sulphate of zinc by the action of this oxide on the dilute sulphuric acid, $ZnO + H^2SO^4 = H^2O + ZnSO^4$. The heat absorbed by the calorimeter during the solution of 1 gramme of zinc was 567·9 gramme-degrees: this, according to the supposition, represented the heat of oxidation of the zinc + the heat of formation of sulphate of zinc from anhydrous oxide and dilute sulphuric acid − the heat absorbed by the decomposition of water. Calling the heat of oxidation of one

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gramme of zinc x, and calculating, from the direct determinations previously recorded, the calorimetric effects of the other processes, we have

$$x = 567{\cdot}9 + 1060{\cdot}4 - 335{\cdot}5 = 1292{\cdot}8.$$

Similarly, when 1 gramme of zinc was dissolved in dilute hydrochloric acid, 503·8 units of heat were absorbed by the calorimeter, and the following equation was obtained to represent the heat of oxidation of that weight of zinc:

$$x = \underset{\substack{\text{Heat absorbed}\\ \text{by calorimeter.}}}{503{\cdot}8} + \underset{\substack{\text{Heat absorbed}\\ \text{by decomposition}\\ \text{of water.}}}{1060{\cdot}4} - \underset{\substack{\text{Heat evolved by}\\ \text{action of dilute}\\ \text{hydrochloric acid on}\\ \text{oxide of zinc.}}}{274{\cdot}3} = 1289{\cdot}9;$$

a result which agrees almost exactly with the foregoing.

This number having been obtained, the heat of oxidation of metallic copper could be deduced in a similar manner from the quantity of heat set free when a known weight of zinc was dissolved in a solution of sulphate of copper. In this way the number 684 was found for the heat of oxidation of 1 gramme of copper.

The following table gives the heats of combination of one equivalent of several metals with one equivalent of various metalloids, deduced from experiments of this kind:—

Metals.	Units of heat evolved by combining with				
	8 grammes oxygen.	35·4 grammes chlorine.	80 grammes bromine.	127 grammes iodine.	16 grammes sulphur.
Hydrogen . .	34462	23783	9322	−3606	2741
Potassium . .	76238*	100960	90188	77268	45638
Sodium . . .	73510*	94847			
Zinc . . .	42451	50296	. .	. .	20940
Iron . . .	37828	49651	. .	. .	17753
Copper . . .	21885	29524	. .	. .	9133
Lead . . .	27675	44730	32802	23208	9556
Silver . . .	6113	34800	25618	18651	5524

Taking the heat developed in the formation of any given compound as a measure of the energy of the affinity of its constituents, a certain definiteness and precision of meaning are given to such terms as strong and weak, active and inert, which are often used in reference to chemical reagents in rather a vague sense; and on comparing the numbers representing the heats of formation of various compounds, they will be found to bear out in a general way the manner in which such terms are commonly applied. The results recorded in the above table, for instance, serve to explain certain facts which have often been quoted as anomalous and opposed to the commonly received idea that the affinities of chlorine are stronger than those of bromine or iodine, and the affinities of bromine stronger than those of iodine. The facts referred to are such as these: the observation of Fehling that in the fractional precipitation of a solution containing both chlorides and bromides with nitrate of silver, the whole of the bromine is contained in the first portions of the precipitate; the similar observation of Field (Chem. Soc. Qu. J. x. 234), and the decomposition of chloride of silver when brought in contact with an aqueous solution of bromide or iodide of potassium, described by the same chemist; and particularly the violent decomposition of chloride of silver, attended with evolution of heat, which takes place, as observed by Deville (Ann. Ch. Pharm. ci. 198), when aqueous hydriodic acid is poured upon it.

The precipitation of bromide or iodide of silver, to the exclusion of the chloride, in cases of fractional precipitation with nitrate of silver, and the conversion of chloride of silver into bromide or iodide by contact with an aqueous solution of iodide of potassium, may be considered as essentially the same phenomenon. When the latter transformation is expressed by an equation, the substances whose formulæ appear in the left-hand member of the equation are those which suffer decomposition; while those which are formed appear on the right-hand side; and on comparing the calorimetric values of the several terms, making due allowance for their state of solution or otherwise, we find that the sum of the calorimetric values on the left-hand side of the equation is less than the sum of the calorimetric values of the substances on the right-hand; thus indicating that, although the conversion of chloride of silver into bromide or iodide by simple substitution would be attended with absorption of heat, the combined effect of all the actions which take place in the experiments under consideration is to cause an evolution of heat.

* These numbers represent the formation of aqueous solutions of potash and soda: all the rest refer to anhydrous compounds.

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Thus we have

	AgCl + KBr	=	AgBr + KCl
Calorimetric values	34800 85678		25618 97091
Sums:	120478		122709

therefore: heat evolved in the reaction = 122709 − 120478 = 2231 gramme-degre

	AgCl + KI	=	AgI + KCl
Calorimetric values	34800 72479		18651 97091
Sums:	107279		115742

therefore: heat evolved in the reaction = 115742 − 107279 = 8463 gramme-degr

Similarly, for the reaction of aqueous hydriodic acid on chloride of silver, we ha

	AgCl + HI	=	AgI + HCl
Calorimetric values	34800 15004		18651 40192
Sums:	49804		58843

therefore: heat evolved in the reaction = 58843 − 49804 = 9039 gramme-degree

The heat evolved in a considerable number of processes of oxidation has bee directly determined by Favre (J. Pharm. Chim. [3] xxiv. 241, 311, 412; Jahre 1853, pp. 22 *et seq.*), for the most part by effecting the oxidations in presence of w in the mercurial calorimeter, by means of hypochlorous acid, whose heat of forma calculated for one equivalent of chlorine, he found by preliminary experiments t − 7370 units.

For the details of this investigation we must refer to the original papers; the important results obtained are as follows, calculated always for one equivalent of element operated upon.

Substance.	Product.	Heat evolved.	Ratio.
Yellow phosphorus	Aqueous phosphoric acid	209476	4·36
Red phosphorus	Aqueous phosphoric acid	181230	
Yellow phosphorus	Phosphoric anhydride	190490	
„ „	Phosphorous acid	140394	2·91
„ „	Hypophosphorous acid	48302	1·
Arsenic	Arsenic acid	110787	1·54
„	Solid opaque arsenious acid	75363	
„	Dissolved opaque arsenious acid	71690	1·
Phosphorus	Pentachloride	100373	
„	Trichloride	94804	
Arsenic	Trichloride	71883	
Nitrogen	Nitrous oxide	−8724	
Nitric oxide	Nitric acid	20655	
Nitrous acid	„ „	27269	
Sulphurous acid	Sulphuric acid	27839	
Sulphur (portion of flowers of sulphur insoluble in sulphide of carbon)	„ „	64110	
Plastic sulphur	„ „	67211	3·32
Sulphur (precipitated from hyposulphite of sodium)	„ „	63407	
Sulphur	Sulphurous acid (Favre and Silbermann)	39373	1·95
Sulphur	Hyposulphurous acid	20233	1·
Selenium	Selenious acid	23206	1·
„	Selenic acid	36360	1·56
Oxalic acid	Carbonic anhydride	30140	
Carbon	Carbonic oxide (Favre and Silbermann)	14838	1·
„	Oxalic anhydride	33410	2·25
„	Carbonic anhydride (Favre and Silbermann)	48480	3·27
Chlorine	Chloric anhydride	−65234	

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It is obvious that, even supposing the principle upon which these indirect determinations are made to be quite correct, and all the interfering circumstances to have been taken into account, the results arrived at cannot be of the same degree of accuracy as those obtained by more direct methods: for the total uncertainty attaching to all the independent data from which they are deduced will be accumulated upon them. Moreover, although a comparison of the heat of chemical action, as determined directly, with that deduced indirectly, generally shows, in the simple cases in which it is possible to institute such a comparison, a degree of agreement which may be taken as a confirmation of the correctness of the principles whereby the calculated result is arrived at, and as proving that, at least in these cases, no modifying circumstance of any great importance has been overlooked in the calculation, still it cannot be considered as proved by existing experiments that the cold of decomposition is *always* equal to the heat of combination. On the other hand, it seems probable, on general grounds, that the calorimetric effect of a given chemical process is not an absolutely constant quantity, but that it is to some extent dependent on accompanying physical conditions. In particular, it seems likely that it must vary more or less with the temperature at which the chemical action takes place, and therefore—to take a particular example—that the heat *evolved* by the combination of mercury with oxygen, at a comparatively low temperature, is not equal to the heat *absorbed* by the decomposition of oxide of mercury at a higher temperature. The equality of these two quantities of heat would involve also the equality of the specific heat of oxide of mercury with the sum of the specific heats of its elements; otherwise, the quantity of heat needed to raise the temperature of a given quantity of mercury and oxygen from the ordinary temperature to a temperature above that at which oxide of mercury is decomposed, would be different, if the two substances remained uncombined during the process, from what it would be if they first entered into combination and afterwards separated again; and since the final condition of the mercury and oxygen would be the same in each case, the difference between the quantities of heat would have disappeared without producing any apparent effect. In the particular case that has been taken as an example, it is possible that the specific heats of the elementary bodies are together equal to the specific heat of the compound, or that the difference may be compensated by the difference in the latent heats of vaporisation of oxygen at the temperature of combination and at that of decomposition. But, although this may be the case, experimental proof that it is so is still wanting; and even if it were afforded here, or for any other particular substance, there would still not be sufficient warrant for assuming as a generally established fact that the cold of decomposition is equal to the heat of combination, independently of the conditions under which these processes respectively occur. In connection with these considerations, it is perhaps worth while to draw attention to the fact that the heat of combustion of hydrogen, deduced by Joule from the electrolysis of water at the ordinary temperature, is decidedly less than that found by other experimenters who determined directly the heat of combustion at a high temperature (see p. 114). These experiments are perhaps not sufficiently comparable in other respects to justify us in attaching much importance to this result; but, taking it as it stands, it is in harmony with the fact that the specific heat of water-vapour is less than the sum of the specific heats of its constituents.

The laws by which Thomsen considers that the development of heat in chemical action is governed, appear to involve views similar to those above explained. The fundamental propositions assumed by him are as follows:—The intensity of the chemical energy of the same body at a constant temperature is unchangeable; the whole quantity of heat developed in a given chemical action is a measure of the chemical energy therein exerted, and is proportional to the difference between the total chemical energy of the reagents and the total chemical energy of the products.

Heat produced by Chemical Decomposition.—There are a few phenomena which are, at least apparently, exceptions to the general rule that heat is evolved in combination and absorbed in decomposition. It was found, for instance, by Favre and Silbermann, that charcoal evolves more heat by burning in nitrous oxide than by burning in pure oxygen. The excess of heat in this case could only be due to heat evolved in the decomposition of the nitrous oxide, and direct experiments proved that this decomposition was attended with evolution of heat. They found further that heat is produced in the decomposition of peroxide of hydrogen by platinum, and from the experiments of Favre, already recorded, it appears that heat is absorbed in the oxidation of chlorine to hypochlorous or to chloric acid. Perhaps these and similar phenomena may be brought into harmony with the general rule, by taking into consideration the evolution of heat due to the combination of two similar atoms to form a molecule, and the corresponding absorption of heat due to the separation of the atoms constituting a molecule of an elementary body.

The influence of high temperature in promoting chemical action—as, for instance,

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between oxygen and hydrogen, which combine when heated, but are without action each other in the cold—is not an exception of the kind here referred to. It is rather thermometric than a calorimetric phenomenon; high temperature being a favourable condition for chemical action in these cases, but in no way its cause. At very low temperatures chemical action appears in all cases to be much retarded: as one illustration, it may be mentioned that when liquefied ammonia, cooled to about $-66°$, is poured upon concentrated sulphuric acid, the two liquids form separate layers, and for some time no action takes place between them (Loir and Drion). Phosphorus and iodine, which combine energetically and with vivid combustion at common temperatures, may be shaken together in a tube cooled by a freezing mixture, without exerting the slightest action on each other.

5. *Relations of Heat to Electricity.*

Electricity produced by Heat.—*Pyro-electricity developed in Crystals.*—To what has been already said on this subject in the article Electricity (ii. 411) we have only to add the results arrived at by Gaugain (Ann. Ch. Phys. [3] lvii. 5) in reference to the pyro-electricity of tourmalines. He finds that this phenomenon obeys the following laws:—(1.) When any number of tourmalines are united by their poles of the same name, they form a battery which produces, under any given circumstances, a quantity of electricity exactly equal to the sum of the quantities which the several tourmalines would produce separately under the same circumstances.

(2.) When several prisms of equal section are superposed, the quantity of electricity developed by the combination is merely equal to that which would be furnished, under the same conditions, by any one of the prisms taken separately.

(3.) The quantity of electricity produced by a prism of tourmaline is proportional to its sectional area, and is independent of its length.

(4.) The quantity of electricity which a tourmaline developes when its temperature is lowered a given number of degrees, is independent of the length of time in which the cooling is effected.

(5.) When a tourmaline is heated a given number of degrees, the quantity of electricity developed is precisely the same as that which would be produced if it were cooled to an equal extent.

Gaugain finds that the development of electricity, consequent on the alteration of the temperature of a tourmaline, is very much more marked if one pole of the crystal is placed in electric communication with the earth, than when the crystal is completely insulated.

Thermo-Electricity.—When two bars of dissimilar metals are soldered together at each end, a current of electricity generally circulates through the circuit formed by them, as long as the two soldering points are at different temperatures. The electromotive force developed at each joint is a function of the temperature, which, in the cases that have been specially examined, may be represented by the formula $E = a + bt + ct^2$, where t is the temperature, and a, b, and c are constants depending on the nature of the metals used. Consequently, the resultant electromotive force, when the temperatures of the joints are t and t respectively, may be represented by

$$e = E - E_1 = b(t - t_1) + c(t^2 - t_1^2) = (t - t_1)[b + c(t - t_1)],$$

which shows that the current vanishes not only when the joints are at the same temperature, or when $t = t_1$, but also when the sum of their temperatures attains a value that is constant for the same pair of metals,—that is when $t + t_1 = -\frac{b}{c}$. (Avenarius, Pogg. Ann. cxix. 406, 637.)

Heat produced by Electricity.—The laws regulating the development of heat by the sudden discharge of frictional electricity, or electricity of high tension, have already been treated of in the article Electricity (ii. 395), and in the same article (p. 470) it has been shown that the heat produced by a continuous current of electricity is the exact equivalent of the chemical action whereby the current is generated. In the application of this rule, the total chemical action throughout the circuit must be taken into account, electrolytic decomposition being counted positive or negative according as the direction of the current which would be generated by it, were it to take place independently of the battery, is the same as that of the battery or the contrary. As further explained in the article referred to, the heat developed in the unit of time by an electric current is related to the intensity of the current and to the resistance of the circuit in the manner expressed by the formula:

$$H = I^2R.$$

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From this it follows that, by diminishing the resistance of the circuit, the electro-motive force remaining the same, the total heat, H, can be augmented indefinitely, the intensity, and therefore also the chemical action in the battery, increasing in proportion to the diminution of resistance. But in any single portion of the circuit, whose resistance is r, the development of heat will attain a maximum for a particular value of r. The heat produced in this part will in fact be $h = I^2 r = \frac{E^2}{(R+r)^2} r$, the value of which last expression reaches a maximum when $R = r$, R being the constant resistance of the remainder of the circuit, including the battery. Hence, in order that as large a quantity of heat as possible may be generated in a given time in the conducting wire, the resistance r of the conducting wire must be made equal to the permanent resistance R of the remainder of the circuit. And, since the heating power of the current represents its total energy, it follows that the same proportion between the external and internal resistance of the circuit is the most advantageous that can be adopted for causing the current to produce changes of any other kind outside the battery.

Thermal phenomena of a particular kind occur when an electric current, instead of traversing a homogeneous conductor, passes from one substance to another. Then, in addition to the development of heat corresponding to the resistance of the conductor, according to the laws stated in the last paragraph, a further development or absorption of heat takes place, depending upon the direction of the current. If the current crosses the point of junction of two dissimilar portions of the circuit, in the same direction as the thermo-electric current which would be generated by the application of heat to this point, then the heat developed there is less than corresponds to the resistance of that portion of the circuit, or, in other words, heat is absorbed; if the current passes the point of junction in the opposite direction, the heat generated is more than what corresponds to the resistance.

With a junction formed of the same two metals, the development or absorption of heat thus occasioned is proportional to the intensity of the current by which the junction is traversed. With combinations of different metals, the extent to which this phenomenon occurs varies with the positions of the metals in the thermo-electric series (ii. 412), being greatest for those combinations which give the most intense thermo-electric currents.

6. *Relations of Heat to Mechanical Energy.*

In preceding parts of this article, we have seen that increase of volume and of elastic force are among the most universal of the effects of heat. In this way heat is constantly producing motion, and when this motion is concentrated in a given solid body, and a definite direction is given to it, as in the steam-engine, heat becomes by far the most important artificial source of mechanical power that we possess. Conversely, innumerable familiar facts supply us with illustrations of the production of heat at the expense of mechanical work. Thus, in all machines there is a certain loss of mechanical energy, the work performed by the machine never representing the full equivalent of the work needed to drive it. That portion of the mechanical energy supplied to the machine which is wasted, so far as the performance of useful work is concerned, is expended in overcoming the passive resistances by which the motion of the machine is opposed; such, for instance, as friction between contiguous surfaces not moving with the same velocity, or the rigidity of straps or cords used to transmit movement from one part to another. But, whenever motion is produced in opposition to friction, or a rigid body is forcibly bent, heat is generated; the mechanical energy expended in producing these effects is lost to the purposes of the machine, but the heat evolved is its representative. Percussion is another means by which mechanical energy can be destroyed and heat generated in its stead. These and similar facts have long attracted the attention of philosophers, and great importance has been attached to them in reference to most of the theories that have been suggested from time to time to explain the nature of heat and the effects which it produces. The following is a quotation from Black's *Lectures on Chemistry* (vol. i. pp. 31, 32), and relates to Bacon's investigations into the nature of heat contained in his treatise *De formâ Calidi*:—

"The only conclusion, however, that he" (Lord Verulam) "is able to draw from the whole of his facts, is a very general one, viz. that heat is motion.

"This conclusion is founded chiefly on the consideration of several means by which heat is produced, or made to appear, in bodies; as the percussion of iron, the friction of solid bodies, the collision of flint and steel.

"The first of these examples is a practice to which blacksmiths have sometimes recourse for kindling a fire; they take a rod of soft iron, half an inch or less in thickness, and, laying the end of it upon their anvil, they turn and strike that end very quickly on its different sides, with smart blows of a hammer. It very soon becomes

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red hot, and can be employed to kindle shavings or wood, or other very combustible matter.

"The heat producible by the strong friction of solid bodies, occurs often in some parts of heavy machinery, when proper care is not taken to diminish that friction as much as possible, by the interposition of lubricating substances; as in the axles of wheels that are heavy themselves, or heavily loaded. Thick forests are said to have taken fire sometimes, by the friction of branches against one another in stormy weather. And savages, in different parts of the world, have recourse to the friction of pieces of wood for kindling their fires. . . . .

"The third example above adduced in the collision of flint and steel, is universally known.

"In all these examples, heat is produced or made to appear suddenly, in bodies which have not received it in the usual way of communication from others, and the only cause of its production is a mechanical force or impulse, or mechanical violence."

From these and many other similar phenomena, it is abundantly clear that, by the expenditure of heat, mechanical work can be effected, and that heat can be produced by the expenditure of work. Dismissing, therefore, for the present, all considerations as to the ultimate nature of heat, we may say that heat and work are mutually convertible, and we have in this section to consider the conditions which regulate the transformation of one of these forms of energy into the other.

Work produced by Heat.—The measure of the work done by heat, when it causes expansion, is obviously the product of the resistance overcome into the space through which the expansion takes place; that is, if r denote the resistance, and v and v' the initial and final volumes of the body which undergoes expansion, the work done by the heat will be represented by

$$A = r(v' - v).$$

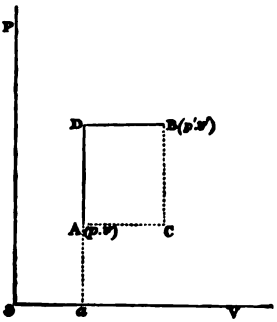
In estimating the resistance by which the expansion of a given body is opposed, it is needful to take into account, not only the external pressure upon its surface, but also, as has been already pointed out (pp. 40 and 73), the molecular forces which tend to maintain unaltered the relative positions of its ultimate particles. The work, A, performed by heat when it causes expansion, must therefore be considered as made up of the *internal work*, a_i, performed in opposition to internal molecular forces, and the *external work*, a_e, expended in overcoming external pressure. In solid and liquid bodies the ratio, $\frac{a_i}{a_e}$, of the internal to the external work is very considerable, but in a perfect gas, the resistance to expansion arising from the mutual attractions of the molecules is insensible, and therefore also the expenditure of work in overcoming this resistance is insensible: hence, in this case $\frac{a_i}{a_e} = 0$, or $a_e = A$. But since it is the external work only which is available for the production of external effects, the consideration of the transformation of heat into mechanical energy is much simpler in the case of gases than in that of liquid or solid bodies; it is further much the most important practically, for although the heat employed in the performance of internal work upon solids or liquids is not necessarily lost ultimately, it is, for the time at least, totally unavailable. We may perhaps compare the transformation of heat into work with the commercial transformation of labour into wealth: then, a perfect gas will represent a medium of transformation comparable with an industrial process which requires no previous expenditure on the part of the workman to enable him to exchange his labour for wages; while a solid or liquid will represent a medium of transformation comparable with a process which can only be carried out by the previous investment of a considerable capital. The capital thus "sunk" may be realised again at some future time, but it represents a certain quantity of labour, which, for the time being, cannot be transformed into wealth.

In order that work may be continuously performed by heat, it is not enough that a portion of air or other gas should be expanded once for all in a cylinder closed by a piston, or in any other similar apparatus. It is true that motion would be thus produced, and that this might be the full equivalent of the heat expended, but the process would soon come to an end. Practically, the extent to which a gas can be expanded so as to produce motion, is very limited, both by the size of the apparatus that can be used and by the temperatures that are attainable. In order that the process may be continuous, the action of the machine, by means of which the transformation is effected, must be periodic: after a certain cycle of changes, all its parts must return to the same relative positions and condition as they had at first, and the air or gas must return to its original pressure and temperature. Such a cycle might evidently be repeated indefinitely, and if any transformation of heat into work were effected by it, the same amount of transformation would take place each time the cycle was completed.

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pages 50 and 51, we saw that in the passage of a gas through a succession of conditions, with respect to temperature, pressure, and volume, which can be represented graphically by a rectangle, and are such that the final state of the gas is the same as its state at the beginning of the process, a certain quantity of heat is expended, which is proportional in amount to the area of the rectangle representing the succession of changes; but it was not there explained what becomes of the heat thus expended.

Fig. 547.



Returning to the consideration of this case, and using the same notation as before, it is plain that, during the passage of the gas from the state A to the state B, through the intermediate stages represented by the lines AD, DB, a quantity of work is performed, which is represented, in kilogramme-metres, by

$$A = p'(v' - v);$$

and that while the gas returns from the condition B to the condition A, along BCA, there is expended a quantity of work represented by

$$A' = p(v' - v);$$

and, therefore, during the whole cycle ADBCA, a quantity of work is ultimately gained equal to

$$A - A' = (p' - p)(v' - v).$$

But, by the last equation on page 51, the amount of heat expended at the same time is

$$Q - Q' = \frac{D}{Ha}(c' - c)(p' - p)(v' - v);$$

therefore, between the heat expended and the work produced, there exists a relation expressed by the equation

$$Q - Q' = \frac{D(c' - c)}{Ha}(A - A') \quad . \quad . \quad . \quad . \quad (n).$$

If we assume that the difference between the specific heat under constant pressure and the specific heat at constant volume is constant for each gas, and is inversely proportional to its density (a relation which is implied in equation (*a*), p. 42), the coefficient of $(A - A')$ in this expression is constant; we may therefore represent it by $\frac{1}{E}$, and write equation (*n*) thus:

$$Q - Q' = \frac{1}{E}(A - A') \quad \text{or} \quad E(Q - Q') = A - A'.$$

That is to say, the heat expended is proportional to the work performed, and *vice versâ*; so that for each kilogramme-degree of heat expended, a quantity of work is performed equal to E kilogramme-metres.

The value of E can be deduced from equation (*n*) by introducing the numerical values of the constants, namely:

$$H = 10{,}333 \text{ kilogr.}, \quad a = 0{\cdot}003665, \quad D = 1{\cdot}293 \text{ kilogr.}$$
$$c' = 0{\cdot}2374, \quad \text{and } c = 0{\cdot}168 \text{ (p. 42).}$$

These values give us:

$$E = 423;$$

that is to say, when heat is transformed into work, every kilogramme-degree of heat (1000 of the heat-units hitherto employed in this article) consumed generates 423 kilogramme-metres of work; or, more generally, the heat needed to raise the temperature of any given weight of water from 0° to 1° C., is equivalent to the amount of mechanical energy required to raise 423 times the same weight of water through one metre from the surface of the earth.

The ratio E is therefore called the **mechanical equivalent** of the unit of heat, and its reciprocal is, as we shall see, the **thermal equivalent** of the unit of work.

That the relation between the heat expended and the work generated is necessarily constant, whatever the process may be by which one is transformed into the other, results from the following considerations. If by one process a unit of heat could be made to perform E units of work, and by another process $E + \epsilon$ units of work could be generated by the same quantity of heat, a portion of the mechanical energy produced in this second process might be expended in reversing the first, so as to regenerate the

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original quantity of heat: thus by combining the two processes, the first being worked backwards, each unit of heat expended would reproduce itself and e units of work *in addition*; there would thus be generation of mechanical energy without any corresponding annihilation of any other form of energy. (The principle here implied, that a given quantity of work is capable of giving rise to as much heat as is needed for its own production, results from the above equation (n), but it will be further considered in what follows.)

Nevertheless, in consequence of the unavoidable defects of all experimental processes, the values of E deducible by different methods are not exactly equal, but the agreement between them is quite sufficient to establish the fundamental principle of the real constancy of the relation between heat and work. A table giving the results of the most important determinations of this ratio will be found further on under the head Heat produced by Work.

Under all circumstances, the quantity of heat which must be employed in order to effect the transformation of a given amount of it into work considerably exceeds the quantity transformed. In the example above considered, the total quantity of heat imparted to the gas was Q; but of the work, A, generated by this amount of heat during the passage of the gas from the state A to the state B, a certain portion, A', was employed, during the return of the gas to its initial state, in regenerating the quantity of heat Q'. The useful work performed was, therefore, $A - A'$, and the quantity of heat transformed was $Q - Q'$, and the ratio of this to the total heat employed, namely, $\frac{Q - Q'}{Q}$, represents the efficiency of the process of transformation, or the value of the engine in which it takes place as a source of mechanical energy. The maximum value which this fraction is capable of attaining, depends on the range of temperature passed through by the fluid which is the medium of transformation. This can be most easily demonstrated in a case where the changes of the volume of the gas take place at constant temperatures; that is, where it is kept at one temperature during the whole process of expansion and at another during the whole process of contraction.

These conditions are approximately realised practically in the air-engine invented by the Rev. Robert Stirling, in 1816. This engine consists essentially of two cylinders; a larger one to which the heat is applied, which we may call, for distinction, the heating cylinder, and a smaller one, which may be called the working cylinder, wherein the tranformation of heat into work takes place. The bottom of the working cylinder is connected by a pipe without a valve with the top of the heating cylinder. Within the heating cylinder is a plunger, composed of non-conducting materials, which occupies nearly half its length, and between it and the sides of the cylinder are passages by which the air can pass from one end to the other when the plunger is raised or lowered. In the working cylinder is a piston which fits it air-tight; this piston and the plunger of the other cylinder are both attached by connecting rods to cranks fixed to the same axle, but making an angle of ninety degrees with each other. The heating cylinder is closed at the top, and the rod from which the plunger hangs passes through an air-tight stuffing box; the working cylinder is open at the top. Heat is applied to the bottom of the heating cylinder, and the upper part is kept cool.

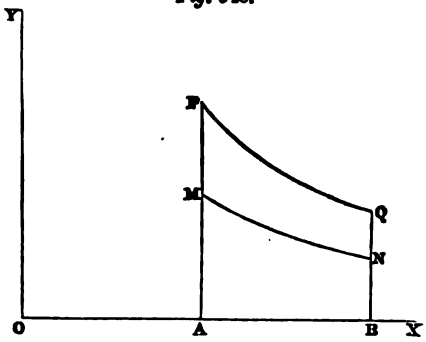
The action of the engine is as follows: Suppose the plunger to be at the top of the heating cylinder, and consequently, the piston in the working cylinder in the middle of its stroke; then, if heat is applied to the bottom of the heating cylinder, the air contained there below the plunger will be expanded, and will press the piston upwards; but the motion of the piston being communicated through the axle to the plunger, the latter will descend, and displacing the heated air from the bottom of the heating cylinder, drive it into the cool space at the top. The elastic force of the air being thus diminished, the piston will be forced down by the pressure of the air upon its upper surface; the plunger now returning to the top of the heating cylinder, the air will be driven to the bottom, where it will be again heated, and the piston will be again forced up by its expansion. Thus by the alternate heating and cooling of the same quantity of air, the motion of the engine is kept up.

In consequence of the manner in which the piston and plunger are respectively connected with the axle, each attains its maximum velocity while the other is at rest, so that the action of the engine during one revolution may be considered as essentially made up of four periods: in the first, the temperature of the air is raised, its volume remaining the same, and consequently its pressure increasing; in the second, the air expands, performing work, but so much heat is imparted to it during the expansion, that its temperature remains constant; in the third period, the temperature of the air is reduced to what it was at the beginning of the first period, its volume being unaltered, and therefore its elastic force being diminished; and in the fourth, it is compressed to its original volume, the heat generated by the compression being withdrawn, so that the air remains at the same temperature throughout the whole process. These four

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successive operations, constituting together one cycle in the action of the engine, may be represented by a diagram such as *fig.* 548, where the abscissa O A represents the volume v_0, of a unit of weight of air at the initial temperature t_0, and the ordinate A M represents the corresponding pressure p_0. The air is first heated, without change of volume, from the temperature t_0 to the temperature t_1; during this operation, its elastic force increases to p_1, represented in the diagram by the ordinate A P; and to effect this change a quantity of heat equal to $c(t_1 - t_0)$ must be imparted to it, c being the specific heat of air at a constant volume; but as no expansion takes place, no work is performed. Next, the air expands from the volume v_0 to the volume v_1, represented by the abscissa O B. Since the temperature of the air is kept constant while it expands, the pressure varies inversely as the volume, a relation represented by the hyperbolic arc P Q, so that the final pressure of the expanded air is represented by the ordinate B Q. During this operation, external work is performed, which is obviously proportional to the area A P Q B, contained between the arc P Q, the axis of abscissæ, and the two ordinates A P and B Q. But in order to prevent the cooling of the gas during its expansion, a quantity of heat, q, must be given to it, of which the mechanical equivalent is exactly the external work which this area represents. In the third operation, the air is cooled to its initial temperature t_0, its volume remaining unaltered, and therefore no work being generated or expended. The pressure is thus reduced from B Q to B N, and a quantity of heat requires to be withdrawn equal to $c(t_1 - t_0)$. Lastly, the air is compressed, while kept at the constant temperature, t_0, to its original volume v_0. To effect this, work must be expended and heat must be removed from the air. The relation between volume and pressure being represented by the hyperbolic arc N M, the work needed for the compression of the air is represented by the area A M N B, and is precisely the mechanical equivalent of the quantity of heat, q', which must be withdrawn from the air in order to maintain its temperature constant during the process.

Fig. 548.



Accordingly, during the first two operations, the air receives a quantity of heat equal to $c(t_1 - t_0) + q$, and develops a quantity of external work geometrically represented by the surface APQB. In the two following operations the air loses a quantity of heat equal to $c(t_1 - t_0) + q'$, and there is expended a quantity of work geometrically represented by the surface AMNB. The ultimate useful expenditure of heat is, therefore, $q - q'$, and the available quantity of work generated is represented by the area MPQN, or the difference between APQB and AMNB. The total expenditure of heat, during the complete cycle of operations, is q; the quantity q' given out by the air during its compression at the temperature t_0 cannot in any way be made available for the maintenance of the action of the machine, and may therefore be considered as entirely lost. The quantity of heat $c(t_1 - t_0)$, which the air gives out when cooled from the temperature t_1 to the temperature t_0, may, on the contrary, be employed to heat another quantity from t_0 to t_1, and, therefore, does not make part of the ultimate expenditure. The reason why this portion of heat can be recovered, while the quantity q' cannot, is, that it is heat of a higher temperature, whereas q', being heat of the temperature t_0, is useless for heating any body to a temperature higher than t_0. The ratio of the useful expenditure of heat to the total expenditure is, therefore, $\frac{q - q'}{q}$.

The values of the quantities q and q' can be found as follows:—representing the mechanical equivalent of heat by E, we have, as a consequence of the above discussion,

$$Eq = \text{surf. APQB}, \quad \text{and } Eq' = \text{surf. AMNB},$$

and consequently

$$\frac{q - q'}{q} = \frac{\text{surf. APQB} - \text{surf. AMNB}}{\text{surface APQB}}.$$

But PQ and MN, being each an arc of a rectangular hyperbola of which the lines of no volume and no pressure, OY and OX, are the asymptotes, it follows that the surface

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APQB is to the surface AMNB as AP to AM. Therefore, $\frac{q - q'}{q} = \frac{AP - AM}{AP}$ $= \frac{p_1 - p_0}{p_1}$. But p_1 and p_0 are the pressures exerted by the same mass of gas under the same volume, v_0, at the two temperatures t_1 and t_0; consequently, $\frac{p_1}{p_0} = \frac{a + t_1}{a + t_0}$ (by equation *b*, p. 45), and—

$$\frac{q - q'}{q} = \frac{p_1 - p_0}{p_1} = \frac{(a + t_1) - (a + t_0)}{a + t_1} = \frac{\tau_1 - \tau_0}{\tau_1},$$

τ_1 and τ_0 representing the absolute temperatures (see p. 52) corresponding to the centigrade temperatures t_1 and t_0.

A similar investigation of any other engine in which work is generated by the expenditure of heat in causing the alternate expansion and contraction of a gas, would lead to the same expression for its maximum efficiency; hence, in every air-engine, whatever its mode of action, provided no heat is spent uselessly in causing changes of temperature, the ratio of the useful expenditure of heat to the total expenditure is equal to the difference of the absolute temperatures between which the engine works, divided by the highest of these temperatures.

The agreement of this theoretical deduction with the results of practical experience, is one of the most conclusive arguments that can be brought forward in favour of the view which regards heat as a mode of energy convertible into mechanical energy, and in opposition to the older view, according to which heat is regarded as an indestructible entity, and the production of mechanical energy by it, as depending upon its transference from a hotter to a colder body. According to this latter theory, the efficiency of an air-engine ought to be much greater than that of a steam-engine,—a conclusion which has not, however, hitherto been confirmed in practice. Taking a special example, the quantity of heat transformed into work, compared with the total heat supplied to a steam-engine, might be calculated upon this theory, as follows:—Let the engine be supposed to be worked at a pressure of 5 atmospheres, and consequently at the temperature 152°. Each kilogramme of saturated steam supplied to the cylinder at this temperature requires for its formation, according to Regnault's experiments (p. 97), 653 kilogramme-degrees of heat, *minus* the heat contained in the water with which the boiler is fed. If we suppose the engine to be worked expansively, down to the pressure of the atmosphere, and that the steam remains saturated during the expansion, it will escape into the atmosphere with the temperature 100°, and when cooled again to the temperature t, of the water supplied to the boiler, each kilogramme will give out $637 - t$ kilogramme-degrees of heat: under these conditions, therefore, the steam only loses, during its expansion in the engine, $(653 - t) - (637 - t) = 16$ degrees of heat out of the whole quantity contained in it. If t, the initial temperature of the water, be 10°, for example, 643 kilogramme-degrees of heat will have been required to generate each kilogramme of steam, and the fraction $\frac{16}{643}$, or not quite $\frac{1}{40}$, will represent the proportion of the total heat which has been converted into mechanical energy. The value of this fraction may be increased somewhat by adding a condenser to the engine, so as to obtain a greater range of expansion. If, for example, the temperature of the condenser is 40°, and the steam expands in the cylinder until its tension is the same as that in the condenser, or 55 millimetres, conditions which are never quite attained in practice, the quantity of heat given up to the condenser by each kilogramme of steam will be $619 - 40 = 579$ kilogramme-degrees; and if the boiler is fed with the condensed water at the temperature 40°, the formation of this quantity of steam will have required $653 - 40 = 613$ kilogramme-degrees. In this case, therefore, $613 - 579 = 34$ parts of heat will be converted into work out of every 613 parts imparted to the boiler: accordingly $\frac{34}{613}$, or very nearly $\frac{1}{18}$, will be the fraction representing the efficiency of the engine.

This calculation (borrowed from Regnault, Mém. Acad. Sciences, xxvi. introd. pp. v. vi.), it will be observed, supposes that all the heat which is not regained in the condenser, or contained in the steam which escapes into the atmosphere, has been converted into work: nevertheless, the efficiency of the engine comes out much below what is actually attained in practice. By careful experiments on large engines, of upwards of 100 horse-power, in which the loss of heat by radiation and conduction, or by other accidental causes, was estimated and allowed for, as accurately as possible, Hirn found that the difference between the quantity of heat supplied to the boiler, and that absorbed by the condenser, amounted to between $\frac{1}{10}$ and $\frac{1}{5}$, on an average to about $\frac{1}{6}$, of the former quantity. Practically, therefore, the steam engine is between twice and three times as efficient a machine as would appear from the above calculation.

The key to this contradiction between theory and practice, lies in a false assumption that has been made in the calculation. It was assumed that, when saturated steam

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expands in the cylinder of a steam-engine, it remains in the state of saturated steam, and the heat contained in it was estimated, in accordance with this supposition, from Regnault's determinations of the total heat of saturated steam at various temperatures. In fact, however, saturated steam, if it performs external work while expanding, suffers partial condensation at the same time, and the latent heat of vaporisation of the steam which condenses becomes available for the production of work in the cylinder. It is not therefore saturated steam which escapes from the cylinder of an engine working under the conditions we have supposed, but a mixture of steam and water, containing a quantity of heat, less than the total heat of vaporisation of an equal weight of saturated steam at the same temperature by the latent heat of vaporisation of the proportion of water present. The necessity of this condensation was deduced by Rankine in 1849, and soon afterwards by Clausius, as a necessary consequence of the existence of the mechanical equivalent of heat, and shown to be the principal cause of the accumulation of water in unjacketed steam-cylinders, which had long been known as a practical inconvenience in the working of steam expansively. The beneficial effect of employing superheated steam, and of enclosing the cylinder in a steam-jacket, is that the steam can then expand, performing external work, without undergoing liquefaction. The condensation of aqueous vapour, when it does work on expanding, is distinctly seen in the formation of a mist under an air-pump receiver, containing moist air, when the piston of the pump is raised.

The fact that a considerable part of the heat supplied to a steam-boiler is consumed in converting the water into steam, is not therefore a reason why an air-engine, in which no portion of heat is similarly expended in causing a change of state, should be more efficient than a steam-engine; and the investigation of the conditions under which work is generated in the steam-engine leads to the general result, that the efficiency of any heat-engine is independent of the nature of the fluid which is the medium of transformation of heat into work, and which may be air, steam, or any other vapour or gas; but that, supposing the reception of heat to take place wholly at one temperature, and the rejection of heat wholly at another, the heat transformed into mechanical energy, is to the whole heat received by the fluid, as the range of temperature is to the absolute temperature at which heat is received, and that, between given limits of temperature, the maximum efficiency is attained when the reception and rejection of heat take place, in the manner just stated, at the highest and lowest temperatures respectively.

The most conclusive confirmation of this result is that when it is applied to the calculation of the mechanical equivalent of heat from Hirn's experiments on large steam-engines already referred to, the mean number found is 413, which differs by only 2½ per cent. from that deduced at the beginning of this section from the thermodynamic properties of air.

Heat produced by Work.—In the introduction to this article (p. 16), it is pointed out as a general fact that heat may be generated by reversing any of its effects. A process by which heat is made to generate work may, therefore, by reversal, become a process for the conversion of work into heat. But, as mentioned at the place quoted, mechanical energy may be transformed into heat by non-reversible processes, such as its expenditure in friction or percussion. There are also indirect methods of transforming work into heat which cannot be reversed, step by step; for instance, mechanical energy, used to give motion to a magneto-electric machine, can be caused to generate electricity, and this electricity, if not expended in effecting chemical changes or in reproducing mechanical energy, takes the form of heat in traversing the conducting wire, although by applying heat to the homogeneous conductor, electricity could not be regenerated. This, therefore, is an indirect, non-reversible, process of transformation. But it is found that whether the process by which mechanical energy, or work, is converted into heat is direct or indirect, reversible or non-reversible, the quantity of heat generated by a given quantity of mechanical energy expended is, within the limits of experimental error, always the same, and, within similar limits, the same as the quantity of heat required to regenerate the original quantity of mechanical energy.

The simplest mode of transforming work into heat, is perhaps the compression of a gas, by which means, as in the familiar experiment of the fire-syringe, a temperature sufficiently high to inflame easily combustible substances can be produced without difficulty. The generation of heat in this manner can be made a continuous process, by alternately compressing the gas at a high temperature and allowing it to expand at a low temperature. The reversal of the four operations represented by the diagram, *fig.* 547, p. 121, would constitute such a process, and by the application of reasoning such as that previously employed in the consideration of this case, it is evident that the work which it would be necessary to expend, in order to effect this reversal, would be represented by $A - A'$, and that the heat generated thereby would be

$$Q - Q' = \frac{1}{E}(A - A'),$$

E, being as before, the mechanical equivalent of heat.

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The expenditure of mechanical energy in compressing liquid and solid bodies is also attended with the production of heat. According to Thomson, the thermal effect of compression may be expressed by the formula:

$$\theta = \frac{\tau a p}{E c},$$

where θ is the effect in question, τ the absolute temperature, a the coefficient of expansion by heat, p the pressure, E the mechanical equivalent of heat, and c the specific heat of the substance. This formula has been verified by Joule (Proc. Roy. Soc. ix. 496) by experiments on water and upon oil, the temperatures varying in the first case between 1·2° C. and 40·4°, and the pressures between 15·64 and 25·34 atmospheres; in the experiments on oil the temperature was always about 17° and the pressures were varied from 7·92 atmospheres to 25·34. In the experiments on water at 1·2°, pressure caused a lowering of temperature instead of a rise, as in the other experiments,—a result which agrees with the fact that water contracts by heat at this temperature. Similarly, when weights are laid upon metallic pillars, heat is evolved, and is absorbed when they are removed, the quantity evolved or absorbed increasing with the weights employed (Joule, *ibid.* viii. 564). Conversely, the stretching of metallic wires causes heat to disappear. Joule found (*ibid.* viii. 355) that an iron wire, $\frac{1}{4}$ inch in diameter was cooled $\frac{1}{4}$ degree C. when stretched by a weight of 775 lb. Similar results were obtained with cast iron, hard steel, copper, and lead. The thermal effects were in all cases found to be almost identical with those deduced from Professor Thomson's theoretical investigation, the particular formula applicable to the case in question being $Q = \frac{\tau a p}{E}$, where Q is the heat absorbed in a wire one foot long, and the other symbols have the same significations as above. Vulcanised india-rubber, which, when stretched, contracts by heat (p. 73), became hotter when the stretching weight was applied, and colder when it was removed. Similar results have been obtained by Edlund, (Ann. Ch. Phys. [3] lxiv. 245), whose experiments lead to the following general conclusions:—

1. When a metal is stretched, without exceeding its limits of elasticity, a cooling effect is produced proportional to the mechanical force employed to stretch it.

2. If the metal afterwards return to the original volume, performing in so doing a quantity of external work equal to that expended in stretching it, it is heated to the same extent as that by which it was previously cooled, and consequently proportional to the mechanical force by which the metal was kept in the stretched state before contracting.

3. If on the other hand, the metal resumes its original bulk without performing external work, it is more strongly heated than in the previous case, and the difference between the two heating effects is proportional to the external work performed, in the one case, by the metal during its contraction.

4. From these three principles, it follows that when a metal passes from the volume V_0 to the volume V_1, without exceeding the limits of perfect elasticity, the accompanying calorific effect does not depend solely upon the initial and final volumes, but also upon the manner in which the entire change takes place.

Experimental Determination of the Mechanical Equivalent of Heat.—It is obvious that any of the processes whereby work is transformed into heat, or heat into work, may serve for the determination of the numerical ratio existing between the unit of work and the unit of heat, provided the process is such as to admit of the accurate measurement of the work or heat expended and of the heat or work produced. The earliest attempt to ascertain the value of this ratio appears to have been made by Count Rumford. His experiments described in his essay, entitled *An Experimental Inquiry concerning the Source of the Heat which is excited by Friction* (read before the Royal Society, January 25, 1798, and published in the Phil. Trans., also in "*Essays, Political, Economical, and Philosophical*, by Benjamin Count of Rumford," 3 vols. 8vo, Lond. 1798–1802, vol. ii. p. 469), were made by pressing a blunt steel borer against the bottom of a cavity made in a brass cylinder which was caused to revolve, while the borer was kept stationary. Considering the state of opinion at the time as to the probable nature of heat, these experiments, and especially the conclusions drawn from them by their author, are very remarkable, but it is only of late years that they have attracted the attention which they deserve. In the most complete experiment, the brass cylinder was placed inside a wooden box containing 18·77 lb. avoirdupois of water; the temperature of the water at the beginning of the experiment was 60° F., and was found to rise continuously when the cylinder was set in motion, until at the end of 2½ hours the water boiled. Rumford states the results of this experiment in a tabular form, taking account of the weights and specific heats of the brass cylinder and steel borer, and gives the total quantity of heat produced, exclusive of the amount accumulated in the wooden box, and of that which was lost by radiation, as sufficient

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to raise the temperature of 26·58 lb. of water 180 degrees Fahrenheit, or from the freezing to the boiling point; he then quotes experiments by Crawford and by himself, from which he concludes "that the quantity of heat produced equably, or in a a continual stream (if I may use that expression), by the friction of the blunt steel borer against the bottom of the hollow metallic cylinder, in the experiment under consideration, was *greater* than that produced equably in the combustion of *nine wax candles*, each $\frac{3}{4}$ of an inch in diameter, all burning together, or at the same time, with clear bright flames."

The two paragraphs which follow this are especially remarkable, as they show that Rumford distinctly saw the source of this heat in the mechanical energy which was expended during its production:—

"As the machinery used in this experiment could easily be carried round by the force of one horse (though, to render the work lighter, two horses were actually employed in doing it), these computations show further how large a quantity of heat might be produced, by proper mechanical contrivance, merely by the strength of a horse, without fire, light, combustion, or chemical decomposition; and, in case of necessity, the heat thus produced might be used in cooking victuals.

"But no circumstances can be imagined, in which this method of procuring heat would not be disadvantageous; for more heat might be obtained by using the fodder, necessary for the support of a horse, as fuel."

After bringing forward arguments and direct experiments to prove that the evolution of heat cannot have been due to an alteration in the capacity for heat of the particles of metal detached from the larger solid masses by the friction, and that it cannot have been furnished by the air, nor by the water, nor by the pieces of metal by which the cylinder and borer were supported, he says:—"It appears to me to be extremely difficult, if not quite impossible, to form any distinct idea of anything capable of being excited and communicated, in the manner the heat was excited and communicated in these experiments, except it be MOTION."

According to Joule's reduction of these results, they indicate that the heat required to raise the temperature of a pound of water one degree Fahr., is equivalent to the mechanical energy represented by 1034 foot-pounds. This number differs considerably from that deduced from the more accurate experiments to be described below; but the difference is of the kind that might have been anticipated, and, considering the manner in which Rumford's experiments were made, it is not excessive. It will be seen that these were not of a kind to furnish accurate data for determining the quantitative relation between heat and work, and it even seems likely that the idea of instituting a comparison between these two quantities first occurred to Rumford after the experiments were finished, his idea, during their performance, having been rather qualitative than quantitative, and his primary object, as indicated in the title of his paper, to ascertain the nature of the source of the heat developed by friction. But, although the numerical results of this investigation were not sufficiently definite to possess any great value, the investigation, as a whole, is of great importance as indicating a distinct stage in the development of ideas concerning the nature of heat and its relations to other forms of energy; and it is for this reason that we have devoted to it so comparatively large a share of space.

These ideas seem to have advanced but little beyond this point until about the year 1842. In that year J. R. Mayer introduced into science the expression "mechanical equivalent of heat" (Ann. Ch. Pharm. xlii. 233; Phil. Mag. [4] xxiv. 371), and thereby—probably as much as by the calculation of the numerical value of this equivalent, founded upon the then inaccurately known ratio of the two specific heats of air—contributed to promote the general adoption of the view that heat and work are mutually convertible. In the same year, Colding, of Copenhagen, communicated to the Royal Society of Denmark experiments on the production of heat by friction, from which he concluded that the evolution of heat was proportional to the mechanical energy expended, and independent of the nature of the substances between which the friction took place. But it was Joule who was the first to publish experiments which were at the same time sufficiently varied and sufficiently accurate to attract the general attention of scientific men, and to be accepted by them as definite proof that the transformation of mechanical energy into heat, or of heat into mechanical energy, takes place in every case according to a constant numerical ratio.

Joule's first experiments, bearing directly upon the subject, were published in 1843 (Phil. Mag. [3] xxiii. 441). In this investigation he showed that the heat evolved by the electric current, furnished by a magneto-electric machine, is proportional to the mechanical energy expended; and that the work done by an electro-magnetic engine is derived from the work of chemical affinity in the battery, work which would otherwise be evolved in the form of heat. From these facts he drew the conclusion, "That the quantity of heat capable of increasing the temperature of a lb. of water by one degree

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of Fahrenheit's scale, is equal to, and may be converted into, a mechanical force capable of raising 838 lb. to the perpendicular height of one foot." In a subsequent paper, read before the Royal Society in 1844 (Phil. Mag. [3] xxvi. 375, 379), he showed that the heat absorbed and evolved by the rarefaction and condensation of air is proportional to the amount of mechanical energy evolved and absorbed in those operations, and obtained a numerical result closely agreeing with that of the electro-magnetic experiments just referred to. In 1845 and 1847 (*ibid.* xxvii. 205; and xxxi. 173) he determined the heat evolved by the friction of water, sperm-oil, and mercury, and obtained the numbers 781·5, 782·1, and 787·6, by experiments on these liquids respectively, as representing the number of foot-pounds which is equivalent to the heat required to raise the temperature of 1 lb. of water 1° Fahrenheit.

Still more elaborate and careful experiments were made by Joule, in 1849 (Phil. Trans. 1850, p. 61; Chem. Soc. Qu. J. iii. 316), upon the friction of water, mercury, and cast-iron, by a method similar to that adopted in those last mentioned. The apparatus employed in this investigation, for the experiments upon water, consisted of a brass paddle-wheel furnished with eight sets of revolving vanes, working between four sets of stationary vanes. This revolving apparatus, of which *fig.* 549 shows a vertical, and *fig.* 550 a horizontal section, was firmly fitted into a copper vessel (see *fig.* 551) containing water, in the lid of which were two necks, one for the axis to revolve in without touching, the other for the insertion of a thermometer. A similar apparatus, but made of iron, and of smaller size, having six rotatory and eight sets of stationary vanes, was used for the experiments on the friction of mercury. The apparatus for the friction of cast-iron consisted of a vertical axis, carrying a bevelled cast-iron wheel, against which a bevelled wheel was pressed by a lever. The wheels were enclosed in a cast-iron vessel filled with mercury, the axis passing through the lid. In each apparatus motion was given to the axis by the descent of leaden weights *w* (*fig.* 551) suspended by strings from the axes of two wooden pulleys, one of

Fig. 549.

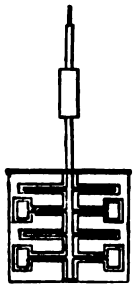


Fig. 550.

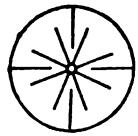
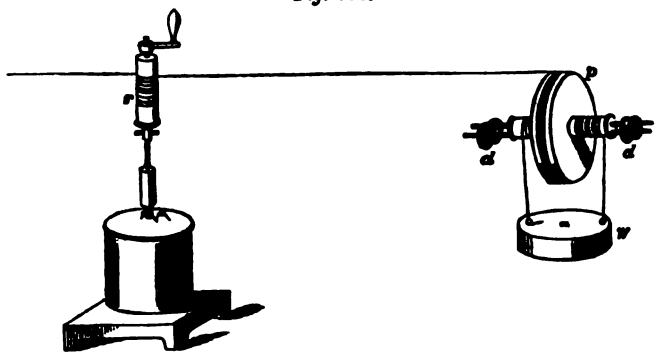


Fig. 551.



which is shown at *p*, their axes being supported on friction-wheels *d d*, and the pulleys were connected by fine twine with a wooden roller *r*, which, by means of a pin, could be easily attached to or removed from the friction apparatus.

The mode of experimenting was as follows: The temperature of the frictional apparatus having been ascertained, and the weights wound up, the roller was fixed to the axis, and the precise height of the weights ascertained; the roller was then set at liberty, and allowed to revolve till the weights touched the floor. The roller was then detached, the weights wound up again, and the friction renewed. This having been repeated twenty times, the experiment was concluded with another observation of the temperature of the apparatus. The mean temperature of the apartment was ascertained by observations made at the beginning, middle, and end of each experiment. Corrections were made for the effects of radiation and conduction; and, in the experiments with water, for the quantities of heat absorbed by the copper vessel and the paddle-wheel. In the experiments with mercury and cast-iron, the heat-capacity

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of the entire apparatus was ascertained by observing the heating effect which it produced on a known quantity of water in which it was immersed. In all the experiments corrections were also made for the velocity with which the weights came to the ground, and for the friction and rigidity of the strings. The thermometers used were capable of indicating a variation of temperature as small as $\frac{1}{100}$ of a degree Fahrenheit.

The following table contains a summary of the results obtained by this method; the second column gives the results as they were obtained from weighings made in air; the third column, the same results reduced to weighings in a vacuum.

Material employed.	Equivalent in air.	Equivalent in vacuo.	Mean.
Water . . .	773·640	772·692	772·692
Mercury . . .	773·762	772·814	774·083
	776·303	775·352	
Cast-iron . . .	776·997	776·045	774·987
	774·880	774·930	

In the experiments with cast-iron, the friction of the wheels produced a considerable vibration of the frame-work of the apparatus, and a loud sound; it was therefore necessary to make allowance for the quantity of force expended in producing these effects. The number 772·692, obtained by the friction of water, is regarded as the most trustworthy; but even this may be a little too high; because even in the friction of fluids it is impossible entirely to avoid vibration and sound. The conclusions deduced from these experiments are:

1. *That the quantity of heat produced by the friction of bodies, whether solid or liquid, is always proportional to the force expended.*

2. *That the quantity of heat capable of increasing the temperature of* 1 *lb. of water (weighed in vacuo, and between* 55° *and* 60° F.) *by* 1° F., *requires for its evolution the expenditure of a mechanical force represented by the fall of* 772 *lbs. through the space of* 1 *foot.*

Or, the heat capable of increasing the temperature of 1 *gramme of water by* 1° C., *is equivalent to a force represented by the fall of* 423·55 *grammes through the space of* 1 *metre. This is consequently the equivalent of "a unit of heat."*

Since, in consequence of the researches that have been mentioned, the attention of scientific men has been prominently called to the mutual equivalence of heat and work, several investigations have been made, either for the express purpose of ascertaining the numerical ratio expressing that equivalence, or involving determinations from which that ratio can be calculated. In the following table, taken from Verdet's *Exposé de la Théorie Mécanique de la Chaleur* (Paris, 1863), the most trustworthy determinations of the mechanical equivalent of heat are put together. The numbers here given represent the number of kilogramme-metres which is equivalent to 1 kilogramme-degree centigrade, or the number of gramme-metres which is equivalent to 1 gramme-degree.

Table of determinations of the Mechanical Equivalent of Heat.

Nature of the phenomenon whence the determination is drawn.	Philosophers who have indicated the theoretical principle of the determination.	Philosophers who have supplied the experimental data.	Mechanical equivalent.
General properties of air . .	Mayer. Clausius.	V. Regnault. Moll and van Beek.	426
Friction	Joule.	Joule.	424
		Favre.	413
Work done by the steam-engine	Clausius.	Hirn.	413
Heat evolved by induced currents	Joule.	Joule.	452
Heat evolved by an electro-magnetic engine, at rest and in motion . . .	Favre.	Favre.	443
Total heat evolved in the circuit of a Daniell's battery	Bosscha.	W. Weber. Joule.	420
Heat evolved in a metallic wire through which an electric current is passing .	Clausius.	Quintus Icilius.	400

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Dynamical Theory of Heat.

For very long, two rival theories have been held regarding the nature of heat: on the one hand, heat has been viewed as having a material existence, though differing from ordinary matter in being without weight, and in other respects; on the other hand, it has been regarded as a state or condition of ordinary matter, and generally as a condition of motion. From the latter part of the last century, until the modern researches upon the mechanical equivalent, the former view had by far the greater number of adherents. Its popularity may be traced chiefly to the teaching of Black and Lavoisier. By the former of these philosophers, the various capacities for heat, or specific heats, of different bodies, seem to have been regarded as analogous to the various proportions of the same acid required to neutralise equal quantities of different bases; while the solid, liquid, and gaseous states were explained by him as representing so many distinct proportions in which heat was capable of combining with ordinary matter. Very similar views were advocated by Lavoisier: he regarded all gases as compounds of a base characteristic of each, with *caloric*, and supposed that when, as the result of chemical action, they assumed the liquid or solid state, this caloric was set free and appeared as sensible heat. Caloric was thus the physical representative of phlogiston, in the same way as oxygen was its chemical representative: the physical portion of the phenomena previously attributed to dephlogistication, being regarded by Lavoisier as caused by the liberation of caloric, just as the chemical portion was explained by him as combination with oxygen. Thus he uniformly speaks (*Traité élémentaire de Chimie*) of the "decomposition" of oxygen-gas by combustible substances, into oxygen (which combines with the combustible) and caloric (which is set free). It is true that Lavoisier guards himself against definitely expressing his belief in the existence of caloric as a substance, but he enumerates it in his list of elements, and seeks to explain all calorimetric phenomena by the analogy of the combination or separation of elementary bodies. Hence, whether regarded by him as necessarily material or not, it became, for his followers, "an imponderable element."

It will be seen that heat was compared to a material substance, by both Black and Lavoisier, in order to explain its then known quantitative relations; and from this point of view, the conception introduced by them had the great advantage of being more easily grasped than any which the advocates of the immaterial nature of heat had to offer in its place. It was much easier to conceive of definite quantities of an exceedingly subtile substance or fluid, than of definite quantities of motion which was itself undefined as to its nature. It was a direct consequence of the material view, that heat should be considered as indestructible and as incapable of being produced, and therefore that the total quantity of heat in the universe should be regarded as at all times the same.

The greatest difficulty which the upholders of the substantial existence of heat had to meet, was its production by mechanical means, a phenomenon of which, as we have seen, several instances were distinctly recognised. Here it was not easy to deny the actual generation of heat, and to explain the effects as depending merely on its altered distribution. Nevertheless, the evolution of heat by friction and percussion was generally considered, by the advocates of the material view, as in some way resulting from a diminution in the capacities for heat of the bodies operated upon; and this explanation derived considerable support from the remark, made by Black, that a piece of soft iron, which has been once made red hot by hammering (see p. 119), cannot be so heated a second time until it has been heated to redness in a fire and allowed to cool. In this case, certainly, it seemed as though the hammering forced out heat from the mass of iron, like water from a sponge, and that a fresh supply was taken up when the iron was put in the fire. But, as has been shown already, this explanation did not satisfy Rumford, who, in the investigation described above, made direct experiments upon the specific heat of the chips of metal detached by the friction, and found it to be identical with that of brass under ordinary circumstances. An experiment which proved, if possible, still more decisively, that the heat generated by friction cannot be ascribed to a diminution in the specific heats of the substances, was made by Davy, in 1799, the year following the publication of Rumford's researches. Davy arranged two pieces of ice, so that they could be caused to rub against each other under the exhausted receiver of an air-pump, but so that it was impossible for heat to be imparted to them by conduction, and found that by friction they were rapidly converted into water, that is to say, into a liquid whose specific heat was twice as great as that of ice. From this experiment Davy drew the same conclusion that Rumford had drawn from his own results, and expressed himself in very similar terms:—"The immediate cause of the phenomena of heat then is motion, and the laws of its communication are precisely the same as the laws of the communication of motion." (*Elements of Chemical Philosophy*, London, 1812, pp. 94, 95.) Similar views were very forcibly

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advocated by Dr. Thomas Young in his *Lectures on Natural Philosophy;* but, by the majority of scientific men, facts such as we have been referring to, though recognised as difficulties in the way of the material theory of heat, were not allowed to cause its rejection. The ease and apparent precision with which the quantitative phenomena of latent and specific heat could be explained, or at least expressed, upon this theory, still caused it to be generally preferred to one which gave a less definite and, as it seemed, more hypothetical explanation of these phenomena. The mechanical, or dynamical theory, which regarded heat as consisting in a state of molecular motion, cannot be said to have been definitely established until it also was made quantitative,—until it was shown that exact numerical laws regulated the production of heat by work or of work by heat, equally with its production during solidification, or disappearance during fusion. This, as we have seen, was effectually accomplished by Joule, and chiefly as the result of his investigations and of others conducted in the same spirit, philosophers have now been compelled to extend their ideas of quantity from matter to energy, and thus has arisen the new science of Energetics, or the quantitative study of the transformations of energy (as chemistry is the quantitative study of the transformation of matter), comprehending and uniting all the different branches of physical science.

We cannot attempt to give anything like an adequate idea of the state of development which the mechanical theory of heat has now reached; but, in order to illustrate the general nature of the theory, and to show in what sort of way the conception that "heat is motion" has been applied to the explanation of such phenomena as have formed the subject of this article, we give here an outline of the view of the constitution of gases which this theory affords, first put forward, in its present form, by Joule (see Ann. Ch. Phys. [3] l. 381) and subsequently developed by Krönig (Pogg. Ann. xcix. 315) and Clausius (*ibid.* 353), and of the explanation of the relations existing between solids, liquids, and gases, which has been deduced from it by the last-named philosopher. The account which follows, of these applications of the dynamical theory, is taken from Watts's Supplement to *Graham's Elements of Chemistry.* It will be seen that the explanations of phenomena which this theory affords, are at least equally definite with those which can be given upon the view of the material nature of heat.

First, then, it is assumed that the particles of all bodies are in constant motion, and that this motion constitutes heat, the kind and quantity of motion varying according to the state of the body, whether solid, liquid, or gaseous.

In gases, the molecules—each molecule being an aggregate of atoms—are supposed to be constantly moving forward in straight lines, and with a constant velocity, till they impinge against each other or against an impenetrable wall. This constant impact of the molecules produces the expansive tendency or elasticity, which is the peculiar characteristic of the gaseous state. The rectilinear movement is not, however, the only one with which the particles are affected. For the impact of two molecules, unless it takes place exactly in the line joining their centres of gravity, must give rise to a rotatory motion; and, moreover, the ultimate atoms of which the molecules are composed may be supposed to vibrate within certain limits, being, in fact, thrown into vibration by the impact of the molecules. This vibratory motion is called, by Clausius, *the motion of the constituent atoms* (*Bewegungen der Bestandtheile*). The total quantity of heat in the gas is made up of the progressive motion of the molecules, together with the vibratory and other motions of the constituent atoms; but the progressive motion alone, which is the cause of the expansive tendency, determines the *temperature.* Now, the outward pressure exerted by the gas against the containing envelope arises, according to our hypothesis, from the impact of a great number of gaseous molecules against the sides of the vessel. But at any given temperature, that is, with any given velocity, the number of such impacts taking place in a given time, must vary inversely as the volume of the given quantity of gas; hence *the pressure varies inversely as the volume or directly as the density,* which is Boyle's law.

When the volume of the gas is constant, the pressure resulting from the impact of the molecules is proportional to the sum of the masses of all the molecules multiplied into the squares of their velocities, in other words, to the so-called *vis viva* or *living force* of the progressive motion.

If, for example, the velocity be doubled, each molecule will strike the sides of the vessel with a two-fold force, and its number of impacts in a given time will also be doubled; hence the total pressure will be quadrupled.

Now we know that when a given quantity of any perfect gas is maintained at a constant volume, it tends to expand by $\frac{1}{273}$ of its bulk at zero for each degree centigrade. Hence the pressure or elastic force increases proportionally to the temperature reckoned from -273° C.; that is to say, to the absolute temperature. Consequently, the *absolute temperature is proportional to the* vis viva *of the progressive motion.*

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Suppose a vessel of the form of a rectangular parallelopiped, the lengths of whose sides are x, y, z, to contain n gas-molecules, each having the mass m. Suppose, also, the space enclosed by this vessel to be divided into $\frac{n}{6}$ equal cubes; and at a given instant let there be in each of these cubes six gas-molecules, moving severally in the directions $+x$, $-x$, $+y$, $-y$, $+z$, $-z$, and with the common velocity c. Let it also be supposed that the molecules exert no mutual action upon each other, but pass without hindrance from side to side of the vessel. It is required to determine the pressure, which the gas exerts against one of the sides, yz, of the vessel. The pressure arising from the impact of a single gas-molecule is mca, if a denote the number of impacts which take place in a unit of time. Now, a molecule moving at right angles to yz, or parallel to x, strikes against yz every time that it passes over the space $2x$; therefore $a = \frac{c}{2x}$.

To find the total pressure P upon yz, the quantity, mca, must be multiplied by the number of molecules which move parallel to x, which number, since two atoms out of every six are parallel to x, is $\frac{n}{3}$. Hence $P = m.c.\frac{c}{2x}.\frac{n}{3}$. And the pressure p upon a unit of surface of the side yz, is $p = m.c.\frac{c}{2x}.\frac{n}{3}.\frac{1}{yz}$; or if we put $xyz = v$, and leave out the constant factor:

$$p = \frac{nmc^2}{v}.$$

This expression shows that the pressure exerted upon a unit of surface is the same for each side of the vessel; also, that the pressure is inversely in proportion to the volume of the gas, which is Boyle's law.

The product, mc^2, or the *vis viva* of an atom, is the expression of the temperature reckoned from the absolute zero, or —273° C.

If, in the preceding value of p, we put $mc^2 = \tau$, we have

$$p = \frac{n\tau}{v},$$

that is to say, when the volume is constant, the pressure varies directly as the absolute temperature. (Krönig.)

If, for two different gases, we suppose p, τ and v, equal, it follows from this expression, that n also must be the same for both. That is to say, at the same temperature and pressure, equal volumes of different gases contain the same number of molecules. Hence also, the mass, m, of a molecule is proportional to the specific gravity, s, of the gas: or, the molecular weights of different substances are proportional to their vapour-densities (taken at temperatures at which the vapours have the properties of true gases).

Clausius, taking into consideration the *vis viva* of the vibratory and rotatory movements as well of the progressive movements, arrives at the expression, $p = \frac{nmc^2}{3v}$, or $pv = \frac{nmc^2}{3}$, which differs from that of Krönig only by a constant factor.

From this equation, it is possible to deduce the mean value of the absolute progressive velocity of the molecules of any gas for any given temperature. It gives, in fact, directly,

$$c^2 = \frac{3pv}{nm},$$

or, putting q for the weight of the gas, and g for the force of gravity,—

$$c^2 = \frac{3gpv}{q},$$

an expression which contains only numerically determinable quantities. Denoting by ρ the density of the gas compared with that of air at 0°, introducing into the formula the known values of the weight of a litre of air and of the force of gravity, taking p equal to the normal atmospheric pressure, and denoting the absolute temperature by τ, the value of c, expressed in metres, becomes

$$c = 485\sqrt{\frac{\tau}{273\rho}},$$

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which gives at 0° C., for Oxygen $c = 461$ metres per second
„ Nitrogen $c = 492$ „ „
„ Hydrogen $c = 1844$ „ „

Hence, the velocity of translation of the molecules of a gas is inversely as the square-root of its density, which gives Graham's law of the diffusion of gases, and the law of their velocity of entrance into a vacuum.

Moreover, as the motions of the constituent particles of a gas depend on the manner in which its atoms are united, it follows that in any given gas the different motions must be to one another in a constant ratio; and, therefore, the *vis viva* of the progressive motion must be an aliquot part of the entire *vis viva* of the gas; hence also the absolute temperature is proportional to the total *vis viva* arising from all the motions of the particles of the gas.

From this it follows that the quantity of heat which must be added to a gas of constant volume in order to raise its temperature by a given amount, is constant and independent of the temperature. In other words, the specific heat of a gas referred to a given volume is constant, a result which agrees with the experiments of Regnault, mentioned at p. 34. This result may be otherwise expressed, as follows: *The total* vis viva *of the gas is to the* vis viva *of the progressive motion of the molecules, which is the measure of the temperature, in a constant ratio.* This ratio is different for different gases, and is greater as the gas is more complex in its constitution; in other words, as its molecules are made up of a greater number of atoms. The specific heat referred to a constant pressure is known to differ from the true specific heat only by a constant quantity (see p. 42).

The relations just considered between the pressure, volume and temperature of gases, presuppose, however, contain conditions of molecular constitution, which are, perhaps, never rigidly fulfilled; and accordingly, the experiments of Magnus and Regnault (p. 48) show that gases do exhibit slight deviations from Gay-Lussac and Boyle's laws. What the conditions are which strict adherence to these laws would require, will be better understood by considering the differences of molecular constitution which must exist in the solid, liquid, and gaseous states.

A movement of molecules must be supposed to exist in all three states. In the *solid state*, the motion is such that the molecules oscillate about certain positions of equilibrium, which they do not quit, unless they are acted upon by external forces. This vibratory motion may, however, be of a very complicated character. The constituent atoms of a molecule may vibrate separately; the entire molecules may also vibrate as such about their centres of gravity, and the vibrations may be either rectilinear or rotatory. Moreover, when extraneous forces act upon the body, as in shocks, the molecules may permanently alter their relative positions.

In the *liquid state*, the molecules have no determinate positions of equilibrium. They may rotate completely about their centres of gravity, and may also move forward into other positions. But the repulsive action arising from the motion is not strong enough to overcome the mutual attraction of the molecules and separate them completely from each other. A molecule is not permanently associated with its neighbours, as in the solid state; it does not leave them spontaneously, but only under the influence of forces exerted upon it by other molecules, with which it then comes into the same relation as with the former. There exists, therefore, in the liquid state, a vibratory, rotatory and progressive movement of the molecules, but so regulated, that they are not thereby forced asunder, but remain within a certain volume without exerting any outward pressure.

In the *gaseous* state, on the other hand, the molecules are removed quite beyond the sphere of their mutual attractions, and travel onward in straight lines according to the ordinary laws of motion. When two such molecules meet, they fly apart from each other, for the most part, with a velocity equal to that with which they came together. The perfection of the gaseous state, however, implies: 1. That the space actually occupied by the molecules of the gas be infinitely small in comparison with the entire volume of the gas.—2. That the time occupied in the impact of a molecule, either against another molecule or against the sides of the vessel, be infinitely small in comparison with the interval between any two impacts.—3. That the influence of the molecular forces be infinitely small. When these conditions are not completely fulfilled, the gas partakes more or less of the nature of a liquid, and exhibits certain deviations from Gay-Lussac and Boyle's laws. Such is, indeed, the case with all known gases; to a very slight extent with those which have not yet been reduced into the liquid state; but to a greater extent with vapours and condensable gases, especially near the points of condensation.

Let us now return to the consideration of the liquid state. It has been said that the molecule of a liquid, when it leaves those with which it is associated, ultimately

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takes up a similar position with regard to other molecules. This, however, does not preclude the existence of considerable irregularities in the actual movements. Now, at the surface of the liquid, it may happen that a particle, by a peculiar combination of the rectilinear, rotatory and vibratory movements, may be projected from the neighbouring molecules with such force as to throw it completely out of their sphere of action, before its projectile velocity can be annihilated by the attractive force which they exert upon it. The molecule will then be driven forward into the space above the liquid, as if it belonged to a gas, and that space, if originally empty, will, in consequence of the action just described, become more and more filled with these projected molecules, which will comport themselves within it exactly like the molecules of a gas, impinging and exerting pressure upon the sides of the envelope. One of these sides, however, is formed by the surface of the liquid, and when a molecule impinges upon this surface, it will, in general, not be driven back, but retained by the attractive forces of the other molecules. A state of equilibrium, not static, but dynamic, will therefore be attained when the number of molecules projected in a given time into the space above, is equal to the number which in the same time impinge upon and are retained by the surface of the liquid. This is the process of vaporisation. The density of the vapour required to ensure the compensation just mentioned, depends upon the rate at which the particles are projected from the surface of the liquid, and this again upon the rapidity of their movement within the liquid, that is to say, upon the temperature. It is clear, therefore, that the density of a saturated vapour must increase with the temperature.

If the space above the liquid is previously filled with a gas, the molecules of this gas will impinge upon the surface of the liquid, and thereby exert pressure upon it; but as these gas-molecules occupy but an extremely small proportion of the space above the liquid, the particles of the liquid will be projected into that space almost as if it were empty. In the middle of the liquid, however, the external pressure of the gas acts in a different manner. There also it may happen that the molecules may be separated with such force as to produce a small vacuum in the midst of the liquid. But this space is surrounded on all sides by masses which afford no passage to the disturbed molecules; and in order that they may increase to a permanent vapour-bubble, the number of molecules projected from the inner surface of the vessel must be such as to produce a pressure outwards, equal to the external pressure tending to compress the vapour-bubble. The boiling point of the liquid will, therefore, be higher as the external pressure is greater.

According to this view of the process of vaporisation, it is possible that vapour may rise from a solid as well as from a liquid; but it by no means necessarily follows that vapour must be formed from all bodies at all temperatures. The force which holds together the molecules of a body may be too great to be overcome by any combination of molecular movements, so long as the temperature does not exceed a certain limit.

The *production* and *consumption of heat* which accompany changes in the state of aggregation, or of the volume of bodies, are easily explained, according to the preceding principles, by taking account of the *work* done by the acting forces. This work is partly external to the body, partly internal. To consider first the internal work:

When the molecules of a body change their relative positions, the change may take place either in accordance with or in opposition to the action of the molecular forces existing within the body. In the former case, the molecules, during the passage from one state to the other, have a certain velocity imparted to them, which is immediately converted into heat; in the latter case, the velocity of their movement, and consequently the temperature of the body, is diminished. In the passage from the solid to the liquid state, the molecules, although not removed from the spheres of their mutual attractions, nevertheless change their relative positions in opposition to the molecular forces, which forces have, therefore, to be overcome. In evaporation, a certain number of the molecules are completely separated from the remainder, which again implies the overcoming of opposing forces. In both cases, therefore, work is done, and a certain portion of the *vis viva* of the molecules, that is, of the heat of the body, is lost. But when once the perfect gaseous state is attained, the molecular forces are completely overcome, and any further expansion may take place without internal work, and, therefore, without loss of heat, provided there is no external resistance.

But in nearly all cases of change of state or volume, there is a certain amount of external resistance to be overcome, and a corresponding loss of heat. When the pressure of a gas, that is to say, the impact of its atoms, is exerted against a movable obstacle, such as a piston, the molecules lose just so much of their moving power as they have imparted to the piston, and, consequently, their velocity is diminished and the temperature lowered. On the contrary, when a gas is compressed by the motion of a piston, its molecules are driven back with greater velocity than that with which they impinged on the piston, and, consequently, the temperature of the gas is raised.

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When a liquid is converted into vapour, the molecules have to overcome the atmospheric pressure or other external resistance, and, in consequence of this, together with the internal work already spoken of, a large quantity of heat disappears, or is rendered *latent*, the quantity thus consumed being to a considerable extent affected by the external pressure. The liquefaction of a solid not being attended with much increase of volume, involves but little external work; nevertheless the atmospheric pressure does influence, to a slight amount, both the latent heat of fusion and the melting point.

We must here mention, in conclusion, a very remarkable consequence of the relation of mutual convertibility which, as we have endeavoured to show, exists between heat and other forms of energy. "Professor William Thomson has pointed out the fact, that there exists (at least in the present state of the known world) a predominating tendency to the conversion of all the other forms of physical energy into heat, and to the uniform diffusion of all heat throughout all matter. The form in which we generally find energy originally collected, is that of a store of chemical power, consisting of uncombined elements. The combination of these elements produces energy in the form known by the name of electric currents, part only of which can be employed in analysing compounds, and thus reconverted into a store of chemical power; the remainder is necessarily converted into heat: a part only of this heat can be employed in analysing compounds, or in reproducing electric currents. If the remainder of the heat be employed in expanding an elastic substance, it may be entirely converted into visible motion, or into a store of visible mechanical power (by raising weights, for example), provided the elastic substance is enabled to expand until its temperature falls to the point which corresponds to the absolute privation of heat; but unless this condition be fulfilled, a certain proportion only of the heat, depending upon the range of temperature through which the elastic body works, can be converted, the rest remaining in the state of heat. On the other hand, all visible motion is of necessity ultimately converted entirely into heat by the agency of friction. There is, then, in the present state of the known world, a tendency towards the conversion of all physical energy into the sole form of heat.

"Heat, moreover, tends to diffuse itself uniformly by conduction and radiation, until all matter shall have acquired the same temperature.

"There is, consequently, Professor Thomson concludes, so far as we understand the present condition of the universe, a tendency towards a state in which all physical energy will be in the state of heat, and that heat so diffused that all matter will be at the same temperature; so that there will be an end of all physical phenomena.

"Vast as this speculation may seem, it appears to be soundly based on experimental data, and to represent truly the present condition of the universe, so far as we know it." (Rankine, Phil. Mag. [4] iv. 359.)

*** For *Radiation and Conduction of Heat*, see RADIATION.

APPENDIX.

The following table gives the temperatures measured by the air-thermometer, at which, according to Regnault's experiments (Mém. Acad. Sciences, xxvi. 658), the vapours of the liquids enumerated in it exert a pressure equal to that of 760 millimetres of mercury:—

Substance.	Temperature	Substance.	Temperature.
Nitrous oxide	− 87·90°	Chloride of silicon	56·81°
Carbonic anhydride	− 78·2	Chloroform	60·16
Sulphydric acid	− 61·8	Methylic alcohol	66·78
Ammonia	− 38·5	Trichloride of phosphorus	73·80
Chlorine	− 33·6	Perchloride of carbon (CCl^4)	76·50
Chloride of methyl	− 23·73	Alcohol	78·26
Oxide of methyl	− 23·65	Benzene	80·36
Sulphurous anhydride	− 10·08	Bromide of ethylene	131·60
Chloride of ethyl	+ 12·50	Oil of turpentine	159·15
Chloride of cyanogen	12·66	Oxalate of methyl	164·20
Chloride of boron	18·23	Oil of lemons	174·80
Ether	34·97	Mercury	357·25
Bromide of ethyl	38·37	Sulphur	448·00
Sulphide of carbon	46·20		

The next table, also from Regnault's experiments (*Op. cit.* pp. 327–332), gives the specific heats of various substances in different states of aggregation. Where, in the column indicating the temperature, some particular degree is given, the number repre-

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senting the specific heat is the *elementary* specific heat at that degree of temperature,—that is, the quantity of heat required to cause a *very small* alteration of temperature in one gramme of the substance, compared with the quantity required to cause a like infinitesimal alteration of temperature in 1 gramme of water. When an interval of temperature is given, the specific heat is the mean specific heat within that interval:—

Substance.	Solid.		Liquid.		Gaseous.	
	Temperature.	Specific Heat.	Temperature.	Specific Heat.	Temperature.	Specific Heat.
Water	− 78° to 0°	0·474	10°	1·0	128° to 220°	0·4805
,,	− 20 to 0	0·504	10 to 100	1·0		
Bromine	− 77·8 to − 25	0·0833	− 7·3 to 10	0·1060	83 to 228	·0555
,			+ 13 to 58	·1129		
Alcohol			− 20	·5053	105 to 220	·4534
,,			0	·5475		
,,			+ 20	·5951		
,,			40	·6479		
,,			60	·7060		
,,			80	·7694		
Ether			− 30	·5113	70 to 220	·4797
,,			0	·5290		
,,			+ 30	·5467		
,,			35	·5497		
Sulphide of carbon			− 30	·2303	73 to 192	·1570
,, ,,			0	·2352		
,, ,,			+ 30	·2401		
,, ,,			45	·2426		
Methylic alcohol			0 to 20	·6700	101 to 223	·4580
Acetone			− 30	·4824	129 to 233	·4125
,,			0	·5064		
,,			+ 30	·5302		
,,			60	·5540		
Sulphydrate of ethyl			20 to 70	·4785	120 to 223	·4008
Chloride of ethyl			− 27·6 to + 4·5	·4276	19 to 172	·2738
Bromide of ethyl			0 to 20	·2160	77·7 to 196·5	·1896
Cyanide of ethyl			− 30	·4325	114 to 221	·4262
,, ,,			0	·5086		
,, ,,			+ 30	·5847		
,, ,,			60	·6608		
,, ,,			90	·7369		
Acetate of ethyl			− 30	·4960	115 to 219	·4008
,, ,,			0	·5274		
,, ,,			+ 30	·5588		
,, ,,			60	·5902		
Chloroform			− 30	·2293	117 to 228	·1567
,,			0	·2324		
,,			+ 30	·2354		
,,			60	·2384		
Chloride of ethylene			− 30	·2790	111 to 221	·2293
,, ,,			0	·2922		
,, ,,			+ 30	·3054		
,, ,,			60	·3186		
Benzene			20 to 71	·4360	116 to 218	·3754
Oil of turpentine			0	·4106	179 to 249	·5061
,, ,,			40	·4538		
,, ,,			80	·4842		
,, ,,			120	·5019		
,, ,,			160	·5068		
Chloride of silicon			0 to 20	·1900	90 to 234	·1322
Trichloride of phosphorus			12 to 98	·2092	12 to 246	·1347
Chloride of arsenic			14 to 98	·1760	159 to 268	·1122
Stannic chloride			14 to 98	·1475	149 to 273	·0939
Tetrachloride of titanium			12 to 98	·1880	162 to 272	·1290

G. C. F.

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HEAVY SPAR. *Barytes. Native Sulphate of Barium.* $Ba''SO^4$.—This mineral occurs in crystals belonging to the trimetric system. Ratio of axes $a : b \cdot c$, 0·6206 : 1 : 0·7618; $\infty\breve{P}$: ∞P in the macrodiagonal principal section = 63° 38′; $\infty\breve{P}2$: $\infty\breve{P}2$ in the same = 102° 18′; $\breve{P}\infty$: $\breve{P}\infty$ in the basal section = 74° 36′; $\breve{P}\infty$: $\breve{P}\infty$ in the same = 100° 40′. *Figs.* 552–556 represent frequently occurring combinations.

Fig. 552.

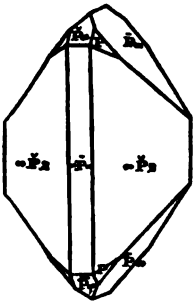


Fig. 553.

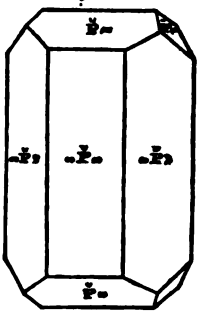


Fig. 554.

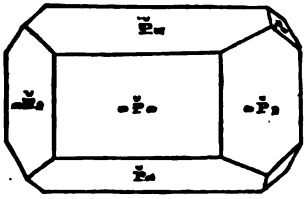


Fig. 555.

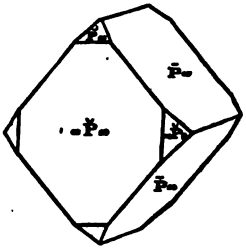
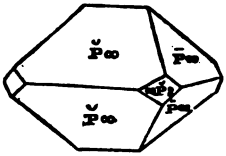


Fig. 556.



The crystals are sometimes prismatically elongated in the direction of one of the axes (*figs. 553, 554*), and sometimes reduced to the tabular form by shortening in one direction (see CRYSTALLOGRAPHY, ii. 149). Cleavage very distinct, parallel to $\infty\breve{P}\infty$. The mineral occurs also massive, with fibrous or laminar structure; also granular. Hardness 2·5 to 3·5. Specific gravity 4·3 to 4·72. Colour white, or inclining to grey, blue, green, yellow, red or brown. Streak white. Lustre splendent, between resinous and pearly. Transparent, exhibiting various degrees of translucency down to perfect opacity. It is sometimes fœtid when rubbed; an impure variety called *hepatite* exhibits this property in a peculiar degree. It decrepitates before the blowpipe, and fuses with difficulty at the edges only. In the inner flame it is reduced to sulphide of barium, and then gives off sulphydric acid when treated with an acid.

Pure heavy spar contains 34·33 per cent. SO^3 and 65·67 Ba^2O; but the mineral generally also contains small quantities of alumina, oxide of iron, silica, and carbonate of calcium. Sulphate of strontium is also a common ingredient. The variety called *calstronbaryte* contains 1 at. lime and 1 at. strontium to 9 at. barium.

It is a very abundant mineral, generally occurring in metalliferous veins, as in the lead-mines of Durham, Cumberland, and Westmoreland. It occurs also in secondary limestones, sometimes in distinct veins, and often in crystals associated with cœlestin and calcspar. In Staffordshire and Derbyshire is found an opaque, massive variety called *cawk*, having an earthy appearance and dirty white colour. On the continent of Europe it is found chiefly at Felsöbanya and Kremnitz, at Freiberg, Marienberg, Clausthal, and Przibram, and at Roya and Roure in Auvergne. Rounded masses, composed of divergent columnar particles, occur at Mount Paterno, near Bologna, hence called *Bolognese stone*. At Freiberg, in Saxony, a variety occurs composed of indistinct prismatic crystals, having a pearly lustre, called *Stangenspath* by Werner. (For the American localities, see Dana, ii. 367.)

Heavy spar occurs altered to calcspar, spathic iron, cerusite, quartz, limonite red iron-ore, pyrites, psilomelane, göthite.

The white varieties of heavy spar are ground and used as a white paint, sometimes alone, but more generally mixed with white lead, the heavy spar alone not possessing sufficient opacity to form a good pigment.

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HEBETIN. Anhydrous silicate of zinc. (See WILLEMITE.)

HEDENBERGITE. A black variety of augite, containing a large quantity of iron, little or no magnesia, and no alumina. Specific gravity 3·5. Found chiefly at Tunaberg, in Sweden.

HEDERA HELIX. *Ivy.*—The seeds of this plant contain a nitrogenous substance resembling emulsin, also fat, two peculiar acids, sugar, a small quantity of pectin, and inorganic salts. From the fresh seeds, ether extracts a green oil, containing a solid and a liquid fat. The former is somewhat difficult to saponify, and yields by saponification a fatty acid, which, after repeated crystallisation from alcohol, melts at a temperature not above 30°, and forms a silver salt containing from 27·4 to 27·6 silver (Posselt). The acids contained in ivy-seeds are described in the next article.

HEDERIC ACID. An acid contained, according to Posselt (Ann. Ch. Pharm. lxix. 62) in the seeds of ivy (*Hedera helix*). It is obtained by treating the seeds with ether to remove fatty matters, and boiling the residue with alcohol, which dissolves the acid, and deposits it, after concentration, in needles or delicate scales, colourless, and insoluble in water and in ether. The acid is inodorous, but possesses in a high degree the acrid taste of ivy-seeds. It gives by analysis, 66·6 per cent. C, and 9·5 H; its rational formula is unknown. It gives off 5·42 percent. water at 100°, and chars without melting at a higher temperature. In contact with strong sulphuric acid it assumes a fine purple colour.

Hederic acid decomposes carbonates, and forms gelatinous salts, most of which are insoluble in water, but soluble in alcohol. Even the *potassium*- and *ammonium*-salts dissolve but sparingly in water, and are deposited as gelatinous precipitates when the solutions are left at rest. The *silver*-salt is deposited from boiling alcohol in white crystals.

Ivy-seeds likewise contain another acid, the presence of which greatly impedes the purification of hederic acid. This acid is uncrystallisable; soluble in water, alcohol and ether; forms soluble yellow salts; precipitates lead-salts, reduces nitrate of silver, and colours ferric salts green. It appears to belong to the family of the tannic acids.

HEDERINE. An alkaloïd said to exist in ivy-seeds. (Vandamme and Chevallier, J. Chim. méd. [2] vi. 581.)

HEDYPHANE. A variety of green lead-ore in which the lead is partly replaced by calcium. Found at Långsbanshytta, in Sweden; also called MIMETENE (*q. v.*)

HELENENE. An oily hydrocarbon produced by distilling helenin with phosphoric anhydride. After rectification, it is yellowish, lighter than water, and has a faint odour resembling that of acetone. Boils between 285° and 295°. Gives by analysis 89·0 to 89·8 C, and 10·1 to 10·4 H, agreeing nearly with the formula $C^{19}H^{28}$ (89·8 C, and 10·2 H). Its formation may perhaps be represented by the equation:

$$C^{21}H^{30}O^{3} = C^{19}H^{28} + H^{2}O + 2CO.$$

The evolution of carbonic oxide has not, however, been actually observed.

Helenene heated with fuming sulphuric acid is converted into *sulpho-helenic* acid, the barium-salt of which contains 17·75 per cent. barium.

HELENIN. $C^{21}H^{30}O^{3}$.—A crystalline substance existing in the root of elecampane (*Inula helenium*); it was first observed by Geoffroy, afterwards examined by Dumas, and more especially by Gerhardt (*Traité*, iv. 296). It may be obtained by distilling the root with water, or better by boiling it with alcohol of 80 per cent.; filtering the solution at the boiling heat, and mixing it with three or four times its volume of cold water. The liquid, after twenty-four hours, deposits helenin in long quadrilateral prisms.

Helenin is perfectly colourless, and has very little taste or odour. It is insoluble in water, but very soluble in alcohol and ether. It melts at 72°, and boils between 275° and 280°, decomposing more or less at the same time.

Helenin is not attacked by alkalis in aqueous or alcoholic solution; but when heated with potash-lime, it yields a resinous compound, which remains combined with the potash. Strong sulphuric acid dissolves it with blood-red colour, forming a conjugated acid. Hydrochloric acid gas is absorbed by it in large quantity.

By *chlorine*, with the aid of heat, it is converted into *chlorhelenin*, perhaps $C^{21}H^{24}Cl^{4}O^{3}$; and by nitric acid into *nitrohelenin*. Phosphoric anhydride converts it into *helenene*.

HELIANTHIC ACID. $C^{14}H^{9}O^{7}, HO$?—An acid obtained from sunflower seeds, belonging, according to Ludwig and Kromayer, to the tannic acid group. By boiling with moderately dilute hydrochloric acid in a stream of hydrogen, it is resolved into fermentable sugar, and an acid violet colouring matter.

HELIANTHUS ANNUUS. *The Sunflower.*— The peeled seeds of this plant

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contain, according to Ludwig and Kromayer (Arch. Pharm. [2] xcix. 1, 285): 1. Helianthic acid.—2. A *fat oil*, amounting to 40 per cent. of the peeled seeds.—3. A small quantity of *fermentable sugar*, uncrystallisable, and capable of reducing cupric oxide, only when the latter is present in considerable quantity in alkaline solution.—4. A substance soluble in alcohol, precipitated from this solution by ether in the form of a syrup, not directly fermentable, and not capable of reducing cupric oxide in alkaline solution, but convertible by boiling, either alone or with acids, into a substance which reduces cupric to cuprous oxide, and perhaps constituting a link between inulin and sugar.—5. *Legumin*.—6. A substance perhaps identical with inulin, insoluble in cold water and alcohol, and converted by boiling with dilute acids into a body which reduces cupric to cuprous oxide.—7. Mulders' horny vegetable albumin (a body resembling cellulose, soluble in strong sulphuric acid, and precipitable from this solution by water).—8. A mixture resembling cerebrin, and another resembling oleophosphoric acid.—9. Cellulose.

The nitrogenous substance, which is soluble in boiling alcohol, and remains as a gelatinous mass when the alcohol is distilled off, appears to be a compound of helianthic acid with a protein-substance, accompanied by a soapy compound.

The peeled seeds dried in the air at mean temperatures yielded 4·2 per cent. ash, of which 3·8 pts. were insoluble, and 0·4 soluble in water.

HELICIN. $C^{13}H^{16}O^{7}$. (Piria, Ann. Ch. Phys. [3] xiv. 287.)—A body produced by the action of very dilute nitric acid upon salicin:

$$\underset{\text{Salicin.}}{C^{13}H^{18}O^{7}} + O = H^{2}O + \underset{\text{Helicin.}}{C^{13}H^{16}O^{7}};$$

also, together with benzoic acid, by boiling benzo-helicin with magnesia (Piria, Ann. Ch. Pharm. xcvi. 380). To prepare it, 1 pt. of pulverised salicin is mixed with 10 pts. of nitric acid of 20° Bm. (specific gravity 1·157), and the mixture is left to itself in an open vessel. In about 24 hours the salicin is completely dissolved, especially if the mixture be stirred from time to time, and crystals of helicin collect at the bottom of the vessel. They must be pressed between paper and purified by washing with ether till the ether which runs off no longer reddens ferric salts. Salicin yields about two-thirds of its weight of helicin.

Helicin crystallises in small, white, very slender needles containing $\frac{3}{4}$ at. water. It is neutral, slightly bitter, sparingly soluble in cold *water*, dissolves very freely in boiling water; it is soluble also in *alcohol*, but is insoluble in *ether*. At 100° C. it gives off its water of crystallisation, amounting to 4·54 per cent. At 175° it melts, and at a higher temperature gives off vapours of hydride of salicyl. Under the influence of *emulsin*, or of dilute *acids* or *alkalis* at the boiling heat, it is resolved into glucose and hydride of salicyl:

$$\underset{\text{Helicin.}}{C^{13}H^{16}O^{7}} + H^{2}O = \underset{\text{Glucose.}}{C^{6}H^{12}O^{6}} + \underset{\text{Hydride of salicyl.}}{C^{7}H^{6}O^{2}}.$$

At ordinary temperatures, the fixed alkalis and alkaline earths merely increase the solubility of helicin in water.

Benzo-helicin. $C^{20}H^{20}O^{8} = C^{13}H^{13}(C^{7}H^{5}O)O^{7}$.—This compound, which is related to helicin in the same manner as populin to salicin, is obtained by dissolving benzo-salicin (populin) in 10 or 12 times its weight of nitric acid of specific gravity 1·3. It crystallises in tufts of silky needles, which do not give off any water when heated. It dissolves in boiling *water*; and if the first drops of a solution filtered at the boiling heat crystallise on cooling, the crystallisation extends throughout the entire mass; but on again applying heat, and leaving the solution to cool slowly and quietly, it solidifies to a gelatinous pulp.

Benzo-helicin is not decomposed by emulsin, but *alkalis* and *acids* convert it into benzoic acid, hydride of salicyl, and glucose:

$$\underset{\text{Benzo-helicin.}}{C^{20}H^{20}O^{8}} + 2H^{2}O = \underset{\text{Benzoic acid.}}{C^{7}H^{6}O^{2}} + \underset{\text{Hydride of salicyl.}}{C^{7}H^{6}O^{2}} + \underset{\text{Glucose.}}{C^{6}H^{12}O^{6}}.$$

By boiling with *magnesia* (or other bases which do not act upon helicin), it is resolved into benzoic acid and helicin.

Brombelicin, $C^{13}H^{15}BrO^{7}.H^{2}O$, is prepared like chlorhelicin, and exhibits similar reactions, but always separates from solution in the gelatinous form, and when dry, forms a dirty white powder without any appearance of crystallisation.

Chlorhelicin, $C^{13}H^{15}ClO^{7}$, exists in two modifications, which may be distinguished as α and β.

α *Chlorhelicin* is obtained by agitating helicin with water in a vessel filled with chlorine. The product is purified by pressure, washing with cold water, and solution in boiling

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water, the liquid as it cools either depositing small needles of monohydrated c helicin, $2C^{13}H^{18}ClO^7.H^2O$, or solidifying to an amorphous jelly containing a l quantity of water.

α Chlorhelicin is inodorous, bitter, nearly insoluble in cold *water*, easily solub hot water and in *alcohol*. The crystals contain 3 per cent. water, which is rather than the amount required by the formula just given (2·76 per cent.), the excess bably arising from admixture of a small quantity of gelatinous α chlorhelicin. heated to between 120° and 130°, they give off the whole of their water, and th maining anhydrous α chlorhelicin, when raised to a higher temperature, give vapours of hydride of chlorosalicyl. This product is likewise obtained, together glucose or its products of decomposition, on heating α chlorhelicin with dilute aci *alkalis*, or by treating it with *emulsin*:

$$C^{13}H^{15}ClO^7 + H^2O = C^{13}H^8ClO^2 + C^6H^{12}O^6.$$

β *Chlorhelicin.* When chlorine is passed into an alcoholic solution of helicin, a v granular substance is obtained, which has the composition of α chlorhelicin, b insoluble in water, nearly insoluble in boiling alcohol, and is not decomposed in manner just mentioned by acids, alkalis, or emulsin.

HELICOÏDIN. $C^{26}H^{32}O^{14}$ (Piria, Ann. Ch. Phys. [3] xiv. 292).—This stance, which may be regarded as a compound of helicin and salicin ($C^{13}H^{1}$ $C^{13}H^{18}O^7$), is obtained by treating salicin with nitric acid still more dilute than which is used for the preparation of helicin, viz. of 12° Bm. (specific gravity 1· It may be purified by washing with cold water and crystallisation from boiling w It forms needles resembling those of helicin, and containing $\frac{3}{2}$ at. water ($2C^{26}H^{34}$ $3H^2O$). Under the influence of emulsin it is decomposed similarly to helicin, yiel however, saligenin in addition to glucose and hydride of salicyl:

$$\underset{\text{Helicoïdin.}}{C^{26}H^{34}O^{14}} + 2H^2O = \underset{\text{Glucose.}}{2C^6H^{12}O^6} + \underset{\substack{\text{Hydride}\\\text{of salicyl.}}}{C^7H^6O^2} + \underset{\text{Saligenin.}}{C^7H^8O^2}.$$

Alkalis and acids act in the same manner, the latter, however, converting the salig into saliretin (C^7H^6O) by abstraction of water.

Helicin, salicin, and helicoïdin are related to one another in the same mann quinone, colourless hydroquinone, and green hydroquinone.

HELIOTROPE or *Bloodstone.* A variety of chalcedony, having a deep g colour with blood-red spots. It is used as a gem.

HELIX POMATIA. The *Garden* or *Vineyard Snail.*—The shell and operc of this mollusc have been analysed by B. Wicke (Ann. Ch. Pharm. cxxv. 79), the following results:—

	$CaCO^3$	$MgCO^3$	Earthy Phosphates.	Ferric Phosphate.	SiO^2	Organic Substance.	
Shell .	96·07	0·98	0·85		1·15	0·95	= 10
Operculum .	86·75	0·96	5·36	0·16	0·35	6·42	= 10

W. Wicke (Ann. Ch. Pharm. lxxvii. 224) found in the operculum 94·24 per c carbonate, and 5·73 per cent. phosphate of calcium, together with traces of ferric oxide phosphate of magnesium. He supposes that the phosphate of calcium is contai chiefly in the small nodules which cover the surface of the operculum. Joy (lxxxii. 365) found in the shell, 98·5 per cent. carbonate of calcium and 1·5 org matter, but no phosphoric acid, silicic acid, fluorine, magnesia, or alkalis. Gobley Pharm. [3] xxxiii. 161) found that the shell contained 70 per cent. water, and w dried consisted almost wholly of carbonate of calcium, with small quantities of ea and ferric phosphates, and animal matter.

In the animal itself, Gobley found a peculiar mucus, containing a small quantit carbonate of potassium, which gives it an alkaline reaction, redissolves in water a drying, but loses this property after a while. Gobley also found, besides the s usually occurring in the animal organism, a small quantity of chloride of ammoni a peculiar compound of animal matter with carbonate of calcium, partially solubl water, and traces of iodine. Beneke (Ann. Ch. Pharm. cxii. 249) found in animal, a peculiar fatty substance called myelin, existing also in the brain and ot organs of the higher animals, which swells up in peculiar forms when soaked in wa

HELLEBORINE. An azotised body contained in the root of black helleb (*Helleborus hiemalis*). It is obtained by exhausting the root with alcohol, dilut the extract with a certain quantity of water, which precipitates a resin, and conc trating the filtered liquid.

It forms colourless crystals, having a harsh bitter taste, soluble in water and alcohol, more soluble in ether. The solutions are neutral to test-paper. It is dec posed by heat, also by nitric and sulphuric acids. Heated with potash it gives

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ammonia. It is not precipitated from its solutions by acetate of lead, chloride of mercury, or iodide of potassium. (W. Bastick, Pharm. J. Trans. xii. 174.)

HELLEFLINTA. Called also *Leelite*. A variety of felspar, occurring at Gryphyttan, in Sweden, having a peculiar waxy lustre and deep flesh-red colour.

HELLENINE and **HELLENIN.** See HELENINE and HELENIN (p. 138).

HELMINTH. A variety of chlorite occurring in felspar and quartz. (Dana, ii. 294).

HELMINTHOLITE. A variety of limestone, generally of a dark colour, and distinguished by the beautiful red and green iridescence of the fossil shells which it contains. It is found in Carinthia, at Halle in the Tyrol, and other localities, and is made into a variety of ornamental articles. (Handw. d. Chem. iii. 848.)

HELVIN. *Tetrahedral Garnet.*—A mineral consisting of silicate of manganese, iron, and glucinum, combined with oxysulphide of manganese. It occurs in regular tetrahedrons. Hardness 6 to 6·5, rather greater than that of felspar. Specific gravity 3·1 to 3·3. Lustre vitreous, inclining to resinous. Colour wax-yellow, inclining to yellowish brown and siskin-green. Streak uncoloured. Subtranslucent. Fracture uneven. On charcoal, in the reducing flame, it melts, with intumescence, to a yellow opaque globule. When finely pulverised it is decomposed by hydrochloric acid, with evolution of sulphydric acid and separation of gelatinous silica.

Analyses: 1, 2. From Saxony, by C. Gmelin (Pogg. Ann. iii. 53). 3. From Norway, by Rammelsberg (*Mineralchemie*, p. 700):

	1	2	3
Silica	35·27	33·26	33·13
Sulphur	—	5·05	5·71
Alumina	1·44	12·03	11·46
Glucina	8·03		
Ferrous oxide	8·00	5·56	4·00
Manganous oxide	42·12	41·76	49·12
Loss by ignition	—	1·15	—
	94·86	98·81	103·42

Hence Rammelsberg deduces the formula

$$2(Mn; Fe)''S \,.\, 3[2(Mn; Fe)''O.2SiO^2 + 2G''O.SiO^2]$$

which is reducible to the form of an orthosilicate united with a protosulphide,

$$3M^4SiO^4.2M^2S.$$

Helvin affords the only known example of a native compound of a silicate with a sulphide. It is found in the gneiss of Schwarzenberg, in Saxony, associated with garnet, quartz, flints, and calcspar: at Breitenbrunn, in Saxony; and on the Hortekalle, a mountain in the Liesthal, near Drammen, in Norway.

HEMIBROMHYDRIN. See BROMHYDRINS.

HEMIHEDRY. See CRYSTALLOGRAPHY (ii. 121, 128, 136, 140, 150, 156).

HEMILOGOUS SERIES. A name applied by Schiel (Zeitschr. Ch. Pharm. 1860, p. 44) to series of organic compounds, the terms of which differ from one another by *n*CH.

HEMIMORPHISM. Hemimorphous crystals, according to most authors, are those which are unsymmetrically terminated at the two ends of the principal axis, *e. g.* siliceous calamine (i. 714), sulphate of magnesium (ii. 150). Laurent, however (Compt. chim. 1849, p. 269), applied the same term to bodies which are similar, or to a certain extent analogous, in composition (*d'une certaine analogie dans leur composition*), and crystallise in forms (belonging to the same or to different systems) in which some of the dihedral angles are nearly equal, while the rest are very unequal.

HEMIMORPHITE. Syn. with SILICEOUS CALAMINE (i. 714).

HEMIPINIC ACID. $C^{10}H^{10}O^6$. (Wöhler [1844], Ann. Ch. Pharm. i. 17.—Blyth, *ibid.* l. 36 and 43.—Anderson, *ibid.* lxxxvi. 194.—Matthiessen and Foster, Proc. Roy. Soc. xi. 58; further, Phil. Trans. 1863; Chem. Soc. J. xv. 346.)—This acid is produced: 1. By the oxidation of opianic acid: $C^{10}H^{10}O^5 + O = C^{10}H^{10}O^6$, which may be effected by the action of peroxide of lead and sulphuric acid (Wöhler), or of aqueous dichloride of platinum (Blyth).—2. By the oxidation of narcotine with dilute nitric acid (Anderson), or with peroxide of lead and sulphuric acid, or per-

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oxide of manganese and hydrochloric acid (Wöhler), or with excess of aqu dichloride of platinum (Blyth). In these reactions, the narcotine is first conve into opianic acid, which then suffers further decomposition.—3. Together with mec by the decomposition of opianic acid under the influence of caustic potash (Matthies and Foster):

$$\underset{\text{Opianic acid.}}{2C^{10}H^{10}O^5} = \underset{\text{Meconin.}}{C^{10}H^{10}O^4} + \underset{\text{Hemipinic acid.}}{C^{10}H^{10}O^6}$$

Preparation.—1. Opianic acid is heated to the boiling point with water and oxide of lead; dilute sulphuric acid is added drop by drop till carbonic acid begi escape; the liquid is left to cool partially; sulphuric acid is then added by drop all the lead is precipitated, and the filtrate is evaporated to the crystallising p The first crystals are sometimes mixed with unaltered opianic acid, but are e purified from it by their much greater solubility in water (Wöhler).—2. The mot liquor resulting from the action of dilute nitric acid upon narcotine (*q. v.*), after separation of meconin, cotarnine and opianic acid, contains hemipinic acid, which be obtained by precipitating this mother-liquor with acetate of lead, and decompo the precipitate with sulphydric acid. (Anderson.)

3. Opianic acid is mixed with a large excess of potash-ley; the liquid is evapor nearly to dryness; and the resulting alkaline mass, consisting of meconin and hemipi of potassium, is dissolved in a moderate quantity of warm water, and mixed with e of hydrochloric acid, whereby the meconin is separated as an oil, carrying down it the greater part of the hemipinic acid. The acidified liquid, when quite col poured off from the solid cake of meconin and hemipinic acid formed at the bot and evaporated to a small bulk, so as to separate the greater part of the chlorid potassium; this salt is washed with alcohol; the alcoholic washings are mixed the concentrated mother-liquor; and the fresh quantity of chloride of potassium precipitated is removed by filtration or decantation. The clear liquid is porated nearly to dryness over the water-bath; the residue thus obtaine again treated with alcohol to separate the last portions of chloride of po sium; and the alcoholic solution is filtered and evaporated. On dissolving product of these operations, together with the original precipitate of meconin hemipinic acid, in boiling water, and rendering the solution slightly alkaline ammonia, nearly all the meconin crystallises out as the solution cools, while hemipi of ammonium remains in solution, together with a small quantity of meconin. complete purification, the solution of the ammonium-salt is precipitated by acetat lead, and the hemipinate of lead, after thorough washing, is decomposed under w by sulphydric acid (Matthiessen and Foster). This mode of preparation is ferable to the oxidation process; because in the latter it is difficult to arrest the ac at the right point, so that there is always a risk, either of leaving opianic acid undec posed, or of losing a portion of the hemipinic acid by further oxidation. (See bel

Properties.—Hemipinic acid crystallises in colourless oblique rhombic pri (Wöhler), or large flat rhombohedrons (Blyth). It has a slightly acid astring taste, and a strong acid reaction. It dissolves with difficulty in cold *water*, more ea in *alcohol* and in *ether*. The crystals effloresce in the air, and give off 13·73 per c (= 2 at.) water at 100° C. At 180° it melts, and solidifies to a crystalline mass cooling. Heated between two watch-glasses, it sublimes in shining laminæ benzoic acid.

Decompositions.—Hemipinic acid burns with a bright flame. Heated with *perox of lead* and *sulphuric acid*, it appears to be completely resolved into water and carbo anhydride (Wöhler); distilled with excess of concentrated *hydriodic acid*, it is c pletely resolved into carbonic anhydride, iodide of methyl, and hypogallic a (Matthiessen and Foster):

$$\underset{\text{Hemipinic acid.}}{C^{10}H^{10}O^6} + 2HI = \underset{\text{Hypogallic acid.}}{C^7H^6O^4} + \underset{\text{Iodide of methyl.}}{2CH^3I} + CO^2$$

Heated with two or three times its weight of strong *hydrochloric acid*—either i sealed tube to about 110°, or in an open vessel connected with a condenser, in s a manner that the condensed vapour flows back into the mixture, and with an ap ratus for evolving hydrochloric acid gas, so that the liquid can be kept constan saturated with acid, it is resolved into carbonic anhydride, chloride of methyl, and acid having the composition $C^8H^8O^4$, homologous, therefore, with hypogallic acid:

$$C^{10}H^{10}O^6 + HCl = CO^2 + CH^3Cl + C^8H^8O^4.$$

This acid (not yet named) crystallises in long transparent prisms, nearly insoluble in c water, not much more soluble in boiling water, more easily soluble in alcohol and eth When heated, it begins to sublime without decomposition at about 200° C., and be a temperature of more than 245° without alteration, but at a still higher temperatu

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it melts, and solidifies to a crystalline mass on cooling. It dissolves in strong sulphuric acid, and crystallises unchanged from a warm saturated solution; a cold solution is not precipitated by water. It gives no coloration with ferric chloride, with nitrate of silver it forms a white precipitate, which blackens on boiling. (Matthiessen and Foster.)

When the mother-liquor from which this acid has crystallised is subjected to the prolonged action of hydrochloric acid, hypogallic acid appears to be formed. (Matthiessen and Foster.)

Hemipinates.—Hemipinic acid is dibasic, its normal salts being represented by the formula $C^{10}H^2M^2O^6$. It is distinguished from opianic acid by forming insoluble salts with *lead*, *silver*, and *iron*. The *ammonium-salt* forms crystals permanent in the air.

The *neutral potassium-salt* is very soluble and difficult to crystallise.

The *acid potassium-salt*, $C^{10}H^2KO^6.\frac{1}{2}H^2O$, forms large hexagonal tables, easily soluble in water and alcohol, insoluble in ether. It gives off its water at 100°.

Barium-salt.—When a solution of hemipinic acid is neutralised with baryta-water, or when solutions of hemipinate of ammonium and chloride of barium are mixed together, the liquid remains clear for a long while if left to itself; but on boiling it for a short time, small, shining crystalline plates of hemipinate of barium are precipitated, and soon fill the liquid, provided the solutions used were not too dilute. The liquid on cooling redissolves this precipitate, and becomes almost or quite clear; but after standing for a few hours, or for a day or two, it again deposits hemipinate of barium, but this time in feathery tufts of very small silky needles; if the liquid be now again heated, these feathery crystals redissolve, and the crystalline plates again make their appearance. This reaction affords the means of recognising hemipinic acid, even when present in small quantity only. (Matthiessen and Foster.)

Ferric hemipinate is a precipitate of a fine orange-yellow colour (Blyth). The *lead-salt* is a white precipitate insoluble in water, but soluble in aqueous acetate of lead, whence it separates in transparent nodules (Wöhler). The *silver-salt*, $C^{10}H^2Ag^2O^6$, is a white precipitate insoluble in water.

Ethyl-hemipinic acid, $C^{10}H^2(C^2H^5)O^6.\frac{1}{2}H^2O$, is obtained by passing hydrochloric acid gas into a solution of hemipinic acid in absolute alcohol. It crystallises in bulky needles, which give off their water (9·6 per cent.) at 100°. It has a strong acid reaction, is very slightly soluble in cold water, rather more in boiling water. The aqueous solution precipitates ferric salts, but not lead- or silver-salts. The ethyl-hemipinates are difficult to purify. The *barium-salt* forms needles grouped in tufts. (Anderson.)

HEPATIN. Syn. with GLYCOGEN (ii. 906).

HEPATITE. A variety of heavy spar containing bituminous matter, and distinguished by the hepatic odour which it emits when rubbed or struck.

HEPTYL. C^7H^{15}. *Œnanthyl.*—The radicle, not yet isolated, of heptylic or œnanthylic alcohol and its derivatives.

HEPTYL, ACETATE OF. $C^9H^{18}O^2 = \left.\begin{matrix}C^2H^3O\\C^7H^{15}\end{matrix}\right\}O$. (Bouis and Carlet, Compt. rend. lv. 140; Ann. Ch. Pharm. cxxiv. 353.—Schorlemmer, Chem. Soc. J. xvi. 217).—This compound is obtained:—1. By heating œnanthol (heptylic aldehyde, $C^7H^{14}O$) with zinc and glacial acetic acid. The nascent hydrogen thereby liberated unites with the œnanthol, forming heptylic alcohol; and this, with the excess of acetic acid forms acetate of heptyl. On washing the product with water, and agitating it with acid sulphite of sodium, to remove undecomposed œnanthol, the acetate of heptyl is obtained as an oil floating on the surface (Bouis and Carlet).—2. By decomposing chloride of heptyl with acetate of potassium. The two substances, mixed with glacial acetic acid, are heated in sealed tubes to 150°—160° C., for twelve hours. The products of the reaction are chloride of potassium, acetate of heptyl, and heptylene. On diluting the contents of the tubes with water, drying the light oily liquid which separates with chloride of calcium, and subjecting it to fractional distillation, the heptylene, which boils at 95°, is easily separated from the acetate of heptyl, the boiling point of which is much higher (Schorlemmer). Alcohol may be used in the preparation instead of glacial acetic acid, but it is less convenient, as the last portions of the chloride are then very slow to decompose, requiring a heat of 200° continued for several days. (Schorlemmer.)

Acetate of heptyl is a colourless oily liquid, lighter than water, having an agreeable fruity odour, and boiling at 180° (Bouis and Carlet), between 179° and 181° (Schorlemmer), which is about 10° higher than it should be according to Kopp's law (p. 90). It contains, according to the mean of Schorlemmer's analyses, 68·18 per cent. carbon, and 11·54 hydrogen, the formula requiring 68·35 carbon and 11·39

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hydrogen.—By distillation with potash-ley, it yields acetate of potassium and heptylic alcohol.

HEPTYL, BROMIDE OF. This compound is slowly produced, with evolution of hydrobromic acid, when bromine is added to hydride of heptyl, and the mixture is either exposed to sunshine or heated in sealed tubes to 100°; the action may be quickened by adding a little iodine. On distilling the product, a large quantity of undecomposed hydride passes over first, and, as soon as the temperature rises to 110°, the residue begins to decompose and blacken. (Schorlemmer, *loc. cit.*)

HEPTYL, CHLORIDE OF. $C^7H^{15}Cl$. (Petersen, Ann. Ch. Pharm. cxviii. 74. —Schorlemmer, Chem. Soc. J. xv. 423; xvi. 217, 426).—Obtained:—1. By the action of pentachloride of phosphorus on heptylic alcohol, and purified by washing and distillation in the usual way (Petersen).—2. By the action of chlorine, or better of chloride of iodine, on hydride of heptyl. Chlorine gas is passed, not in excess, into a solution of iodine in hydride of heptyl; the unattacked portion of the hydride is then distilled off, and the chloride of heptyl is separated by fractional distillation from the portion boiling between 140° and 160° (Schorlemmer).—3. In like manner, from ethyl-amyl ($C^2H^5.C^5H^{11}$), which is isomeric with hydride of heptyl. The product yields, by fractional distillation, two liquids of constant boiling point, *viz.*, chloride of heptyl, and monochlorinated chloride of heptyl, which are easily separated by distillation, as their boiling points differ by 40°. (Schorlemmer, Chem. Soc. J. xvi. 426.)

Chloride of heptyl is a colourless liquid, having an agreeable fruity odour, and burning with a smoky green-bordered flame. Specific gravity 0·891 at 19°. (Schorlemmer); 0·9983 at 55° (Petersen). Boiling point of the chloride obtained from castor-oil alcohol = 175° (Petersen); of that obtained from hydride of heptyl or from ethyl-amyl = 150° (Schorlemmer). This difference seems to point to the existence of two isomeric modifications of chloride of heptyl. Neither boiling point agrees very well with that calculated according to Kopp's law (p. 91): for the average difference for homologous chlorides of the alcohol-radicles, C^nH^{2n+1}, is about 30°, chloride of ethyl boiling at 11°, and chloride of amyl at 101°: hence chloride of heptyl should boil at about 161°.

Chloride of heptyl contains, according to Petersen's analyses, from 61·68 to 62·25 per cent. carbon, 11·01 to 11·28 hydrogen, and 26·46 chlorine, the formula requiring 62·45 C, 11·16 H, and 26·36 Cl. It is insoluble in *water*, but dissolves easily in *alcohol* and *ether*. Heated in a sealed tube with *acetate of potassium* and alcohol or glacial acetic acid, it yields acetate of heptyl (p. 141); and when heated in like manner with alcoholic *sulphydrate of potassium*, it yields sulphydrate of heptyl. It is scarcely acted upon by strong *potash-ley*, even when heated with it in sealed tubes to 180° for several days, only a small quantity of heptylene being formed, and not a trace of heptylic alcohol. (Schorlemmer.)

Monochlorinated Chloride of Heptyl, $C^7H^{14}Cl.Cl$, isomeric, if not identical, with chloride of heptylene, $C^7H^{14}Cl^2$, is obtained, together with chloride of heptyl, by the action of chloride of iodine on ethyl-amyl (see above). It boils at 190°, and gives by analysis 41·85 per cent. chlorine, the formula requiring 42·01. (Schorlemmer.)

HEPTYL, HYDRATE OF. $C^7H^{16}O = \left.\begin{matrix}C^7H^{15}\\H\end{matrix}\right\}O$. *Heptylic* or *Oenanthylic alcohol*.—This alcohol occurs, together with others, in the fusel-oil from the brandy distilled from marc of grapes (*Weintreber-fuselöl*). The portion of this liquid boiling above 133° C. contains several alcohols of the series $C^nH^{2n+2}O$, higher than amylic alcohol; and by subjecting it to repeated fractional distillation, a portion may be obtained which boils between 155° and 160°, and exhibits the composition and reactions of heptylic alcohol. (Faget, Bull. Soc. Chim. de Paris, 1862, p. 59; Ann. Ch. Pharm. cxxiv. 355.)

Heptylic alcohol is likewise obtained:—1. By the action of nascent hydrogen on œnanthol, $C^7H^{14}O$ (Bouis and Carlet). The œnanthol is treated with zinc and glacial acetic acid, as already described (p. 143), and the resulting acetate of heptyl, distilled with potash, yields the alcohol.—2. From hydride of heptyl, that compound being first converted into chloride, the chloride into acetate, and the acetate into the alcohol by distillation with potash. (Schorlemmer.)

3. By distilling ricinoleate of potassium or sodium with excess of the caustic alkali (i. 98). When castor-oil is saponified with potash and the resulting soap (ricinoleate of potassium) is distilled with excess of solid potash, hydrogen is evolved, and an oily liquid passes over, containing an alcohol, or perhaps two, homologous with ethylic alcohol, together with an aldehyde or an acetone, while sebate of potassium remains in the retort. Bouis, who first observed this reaction, originally regarded the volatile oily product as octylic or caprylic alcohol (Compt. rend. xxxiii. 144; Ann. Ch. Pharm. lxxx. 304). Soon afterwards (Institut, 1851, p. 258; Ann. Ch. Pharm. lxxx. 306) he pronounced it to be heptylic alcohol; but ultimately (Compt.

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rend. xxxviii. 935; xli. 603; Ann. Ch. Pharm. xcii. 395; xcvii. 34; in detail, Ann. Ch. Phys. [3] xliv. 77; xlviii. 99), after having succeeded in purifying the alcohol more completely than before, he returned to his first opinion, which was corroborated by the analysis of several derivatives of the alcohol by himself, and also by Moschnin (Ann. Ch. Pharm. lxxxvii. 111), Squire (Chem. Soc. Qu. J. vii. 108), and Cahours (Ann. Ch. Pharm. xcii. 399).—On the other hand, Railton (Chem. Soc. Qu. J. vi. 205), from a determination of the vapour-density, and Wills (*ibid.* 307), from an analysis of the alcohol, and from the examination of some of its compound ethers, concluded that it is heptylic alcohol. Somewhat later, Limpricht (Ann. Ch. Pharm. xciii. 242) showed that the oily distillate obtained as above contains a considerable quantity of a liquid which forms a crystalline compound with acid sulphite of sodium; and by distilling this compound with excess of caustic alkali, he obtained a liquid having the composition of octylic or caprylic aldehyde, $C^8H^{16}O$, which he accordingly regarded as the chief product of the distillation of ricinoleic acid with excess of potash. According to Städeler, however (J. pr. Chem. lxii. 241; Jahresber. 1857, p. 361), the compound $C^8H^{16}O$ is not caprylic aldehyde, but the isomeric compound, methyl-œnanthyl, $CH^3.C^7H^{13}O$, belonging to the class of acetones (i. 31), and its formation takes place simultaneously with that of heptylic alcohol, in the manner shown by the equations:

$$\underset{\text{Ricinoleic acid.}}{C^{18}H^{34}O^3} + 2KHO = \underset{\text{Methyl-œnanthyl.}}{CH^3.C^7H^{13}O} + \underset{\text{Sebate of potassium.}}{C^{10}H^{16}K^2O^4} + 2H^2$$

$$\underset{\text{Ricinoleic acid.}}{C^{18}H^{34}O^3} + 2KHO = \underset{\text{Heptylic alcohol.}}{C^7H^{16}O} + \underset{\text{Sebate of potassium.}}{C^{10}H^{16}K^2O^4} + \underset{\text{Marsh gas.}}{CH^4}$$

The evolution of marsh gas, which the latter equation supposes, has not, however, been observed: the gas evolved appears to be in all cases pure hydrogen. Städeler's analysis of the alcohol agrees very closely with the formula of heptylic alcohol. Similar results have been obtained by Petersen (Ann. Ch. Pharm. cxvii. 69), who analysed the alcohol after carefully freeing it from methyl-œnanthyl, and also some of its derivatives, all of which gave results agreeing with the 7-carbon formulæ. On the other hand, Dachauer (Ann. Ch. Pharm. cvi. 269), from his analyses of the carefully-purified alcohol and several of its derivatives, has come to the conclusion that the volatile products of the reaction are methyl-œnanthyl and octylic alcohol, the formation of the latter differing from that of the former, only by the evolution of 2 at. hydrogen instead of four:

$$\underset{\text{Ricinoleic acid.}}{C^{18}H^{34}O^3} + 2KHO = \underset{\text{Octylic alcohol.}}{C^8H^{18}O} + \underset{\text{Sebate of potassium.}}{C^{10}H^{16}K^2O^4} + H^2.$$

From these various statements it appears probable that both heptylic and octylic alcohol may be produced in this reaction. It must be observed, however, that the percentage of carbon in the two alcohols differs by only 1·4 per cent., and that the percentage of carbon in heptylic alcohol (72·4) might easily be raised to that of octylic alcohol (73·8) by the admixture of a certain quantity of methyl-œnanthyl, which contains more carbon than either of them (75·0 per cent.), and is very difficult to separate from the alcohol. It is possible, therefore, that the alcohol obtained may be in all cases the heptylic, but that some chemists who have analysed it have not succeeded in completely removing the methyl-œnanthyl. On the other hand, assuming the received formula of ricinoleic acid to be correct (and it is confirmed by Petersen's analyses, *loc. cit.*), the formation of the 7-carbon alcohol, together with sebacic acid, does not account for the whole of the carbon, unless we suppose marsh gas to be evolved, which has not been observed by any one. The subject, therefore, requires further investigation.

Preparation of Heptylic alcohol from Castor-oil.—The oil is saponified with caustic soda, and the ricinoleate of sodium, separated in the usual way by common salt, is distilled by small portions with excess of caustic soda, as long as the distillate continues to pass over colourless. The portion collected between 170° and 180° is rectified over solid potash, washed, and shaken up with a concentrated solution of acid sulphite of sodium; and the thick pulp which forms after a while is separated from the mother-liquor by pressing it and transferring it to a moist filter. The whole mass is then repeatedly agitated with ether, in which the alcohol is soluble, but the compound of the acetone with the alkaline sulphite is insoluble. The ethereal solution is then filtered off; the ether removed by distillation, the residual oil again mixed with strong solution of acid sulphite of sodium, and set aside for several days; the watery liquid again separated from the mass, which has now become gelatinous; this mass is exhausted with ether; and the oil obtained from this ethereal solution is again treated several times with sulphite of sodium, being ultimately left in contact with it for several weeks, or as long

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as any small quantity of gelatinous precipitate continues to separate. The oil finally obtained after evaporating the ether is rectified over a small quantity of hydrate of potassium, then washed with water and dried. The product thus obtained is heptylic alcohol. (Petersen.)

Properties.—Heptylic alcohol is a colourless oily liquid, insoluble in water, soluble in common alcohol and in ether. Specific gravity 0·819 at 23° (Städeler). Vapour-density 4·34 (Petersen), 4·16 (Faget), 4·019, by determination in an atmosphere of hydrogen (Railton): by calculation (2 vol.) = 4·04. Boiling point 179° (Wills), between 177 and 177·5° (Städeler), 178·5° (Petersen), 165° (Bouis and Carlet), between 155° and 160° (Faget). These differences, as with the chloride, indicate the existence of two modifications of the alcohol. The calculated boiling point, according to Kopp's law, is 173° (p. 90), so that the heptylic alcohol obtained from castor-oil appears to be the normal compound, whereas the alcohol obtained from brandy fusel-oil, and that produced from œnanthol, appear to correspond with Wanklyn and Erlenmeyer's β-hexylic alcohol, inasmuch as the latter boils at 134°, and 137 + 19 = 156.

The following table exhibits the composition of heptylic alcohol as determined by calculation and by analysis:

	Calculation.		Wills.	Städeler, *mean.*	Petersen.	Faget.	Schorlemmer, *mean.*
C^7	84	72·4	72·79	72·33	72·21	72·43	72·25
H^{16}	16	13·8	13·67	13·55	13·99	13·84	14·24
O	16	13·8	13·54	14·12	13·80	13·73	13·51
$C^7H^{16}O$	116	100·0	100·00	100·00	100·00	100·00	100·00

Faget's alcohol was obtained from brandy fusel-oil (p. 144); Schorlemmer's was prepared from hydride of heptyl obtained from Boghead naphtha; the other three from castor-oil. Petersen observes that the purification of the alcohol did not always succeed so completely as in the sample whose analysis is above given; in one specimen he found 72·95 per cent. carbon and 13·37 hydrogen. Bouis, Moschnin, and Dachauer, as already observed, have obtained, by their analyses of the castor-oil alcohol, results agreeing more nearly with the formula $C^8H^{18}O$, viz. Bouis, 73·5 C, 13·9 H; Moschnin, 73·6 C, 13·8 H; Dachauer, 73·8 C, 13·9 H (calc. 73·8 C, 13·8 H). See OCTYLIC ALCOHOL.

Decompositions.—1. Heptylic alcohol distilled with *chloride of zinc*, yields heptylene, C^7H^{14} (Bouis and Carlet).—2. Heated with *potash-lime*, it gives off hydrogen, and is converted into œnanthylic acid, $C^7H^{14}O^2$ (Faget).—3. With *pentachloride of phosphorus*, it yields chloride of heptyl (Petersen), and with *iodine* and *phosphorus*, iodide of heptyl (Schorlemmer).—4. With *sulphuric acid*, it forms heptyl-sulphuric acid, $C^7H^{16}SO^4$ (Petersen).

HEPTYL, HYDRIDE OF. $C^7H^{16} = C^7H^{15}.H$.—This compound occurs, together with several of its homologues, in rectified American petroleum (Pelouze and Cahours, Compt. rend. lvi. 505; Ann. Ch. Pharm. cxxvii. 196.—Schorlemmer, Proc. Lit. Phil. Soc. Manchester, March 13, 1863; Chem. Soc. J. xvi. 216) and in the light oil obtained from the tar of cannel-coal (Schorlemmer, Chem. Soc. J. xv. 423): it is also produced, together with some of its homologues and other hydrocarbons, by distilling amylic alcohol with chloride of zinc. (A. Wurtz, Compt. rend. lvi. 1164, 1246; Ann. Ch. Pharm. cxxviii. 225.)

1. Rectified American petroleum may be separated by fractional distillation into the hydrides of twelve alcohol-radicles, from hydride of tetryl, C^4H^{10}, boiling at a few degrees above 0°, to hydride of pentadecatyl, $C^{15}H^{32}$, boiling between 255° and 260°, besides others of still higher boiling point (see HYDRIDES). When the liquid which remains after the separation of the hydrides of amyl, boiling at 30°, and hexyl, at 68°, is submitted to further rectification, the temperature remains constant for some time between 90° and 96°; and if the portion which passes over between these temperatures be collected apart and again carefully rectified, the quantity of material being somewhat considerable, a product may be isolated which, after purification by shaking it up with very concentrated sulphuric acid, washing with dilute carbonate of sodium, and dehydration with chloride of calcium, boils between 92° and 94°: this is hydride of heptyl. (Pelouze and Cahours.)

2. The mixture of oils obtained by distilling cannel-coal at as low a temperature as possible, is left in contact for several days with an equal volume of sulphuric acid, and frequently shaken; the oil is then poured off, washed with water, and distilled; and the distillate, consisting of benzene and benzylene (toluene), together with the hydrides of the alcohol-radicles, is repeatedly shaken with strong nitric acid, to convert the benzene and benzylene into nitro-compounds, until, on adding water to the liquid, no further separation of these compounds occurs. The portion unacted upon by the nitric acid is then washed with water, dried over potash, and repeatedly rectified over sodium. The liquid thus obtained yields by fractional distillation, hydride of amyl, C^5H^{12}, boiling at

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39°—40° C., hydride of hexyl at 68°—70° hydride of heptyl at 98°—99°, and hydride of octyl at 119°—120°. (Schorlemmer.)

3. The distillate obtained by heating amylic alcohol with chloride of zinc consists of amylene and compounds polymeric with it, together with hydride of amyl, and smaller quantities of the hydrides of hexyl, heptyl, &c., up to $C^{10}H^{22}$. Heptylene and hydride of heptyl are contained in the portion of the distillate boiling between 85° and 95°, and may be separated by converting the heptylene into a bromide and distilling, the hydride of heptyl then passing over first. (Wurtz.)

Hydride of heptyl is a thin mobile liquid, having a faint but pleasant odour, and burning with a slightly smoky flame. Specific gravity 0·7122 at 16°; 0·709 at 17·5° (Schorlemmer). Boils at 98°—99° (Schorlemmer), at 92°—94° (Pelouze and Cahours). Vapour-density by experiment, 3·49—3·59 (Schorlemmer), 3·616 (Pelouze and Cahours); by calculation (2 vol.) = 3·46. It gives by analysis 83·93 and 84·0 per cent. carbon, 16·13 and 16·1 hydrogen, the formula requiring 84 C and 16 H (Schorlemmer). By *chlorine*, and more quickly by *chloride of iodine*, it is converted into chloride of heptyl. Chlorine passed into hydride of heptyl forms, besides chloride of heptyl, small quantities of some other chlorine-compounds, which, when distilled with sodium, yield a liquid boiling at 95°—100°, and having the odour and composition of heptylene (Schorlemmer, Chem. Soc. J. xv. 424). With *bromine*, hydride of heptyl appears to yield bromide of heptyl (p. 144).

HEPTYL, IODIDE OF. $C^7H^{15}I$.—Obtained by the action of iodine and phosphorus on heptylic alcohol (Schorlemmer, Chem. Soc. J. xvi. 219.—Petersen, Ann. Ch. Pharm. cxviii. 74). It is a colourless liquid, heavier than water, quickly turning brown in contact with the air, boiling at 190° (Schorlemmer), 192° (Petersen). Composition by analysis, 37·19 per cent. C, 6·73 H, and 56·18 I; by calculation, 37·17 C, 6·64 H, and 56·19 I. It is instantly decomposed by alcoholic nitrate of silver, the whole of the iodine being separated as iodide of silver. (Schorlemmer.)

HEPTYL, SULPHYDRATE OF. $C^7H^{15}S = C^7H^{15}.H.S.$—Obtained by heating chloride of heptyl with alcoholic sulphydrate of potassium in a sealed tube. Colourless liquid, boiling between 155° and 158°, having a mercaptan-like, as well as aromatic, odour, and exhibiting all the characteristic reactions of the mercaptans. (Schorlemmer.)

HEPTYLAMINE. $C^7H^{17}N = N.H^2.C^7H^{15}$.—Obtained: 1. By saturating iodide of heptyl with ammonia, heating the solution in the oil-bath, and removing the iodine with oxide of silver (Petersen, *loc. cit.*).—2. By heating chloride of heptyl with ammonia in sealed tubes to 120° for several days. The chlorides of the different heptyl-ammoniums are then formed, but chiefly chloride of heptyl-ammonium, $C^7H^{15}Cl$. This salt dissolves easily in water and alcohol, and crystallises in small scales. When distilled with caustic potash, it yields heptylamine, as a light oily liquid, having an ammoniacal aromatic odour, a burning taste, and boiling at 145°—147°. It is moderately soluble in water, and separates out again on addition of caustic potash. (Schorlemmer, Chem. Soc. J. xvi. 221.)

The *platinum-salt*, $2C^7H^{15}NCl.PtCl^4$, is slightly soluble in cold water, freely soluble in hot water, also in alcohol and ether, crystallising from these solutions in small yellow scales. Gives by analysis 30·7 per cent. platinum (Schorlemmer); 30·9 (Petersen); calc. 30·79.

HEPTYLAMYLIC ETHER. $C^{12}H^{26}O = C^7H^{15}.C^5H^{11}.O$. *Amylœnanthylic ether.*—Produced by the action of heptylate of sodium on an equivalent quantity of iodide of amyl, and obtained, though with some difficulty, by submitting the product to fractional distillation, as a colourless mobile liquid, boiling between 220° and 221°. Specific gravity = 0·808 at 20°. Vapour-density: obs. = 6·57; calc. (2 vols.) = 6·45. Analysis 77·0 per cent. C, and 13·8 H. Calculated composition, 77·4 C, 14·0 H, and 8·6 O. (Wills, Chem. Soc. J. vi. 316.)

HEPTYLENE. C^7H^{14}. *Œnanthylene.*—This hydrocarbon, homologous and polymeric with ethylene, is contained, together with others of the series C^nH^{2n}, and hydrocarbons belonging to the series C^nH^{2n+2} and C^nH^{2n-6}, in the light oil obtained by the distillation of Boghead coal. By treating this oil with bromine in presence of water, the hydrocarbons C^nH^{2n} are converted into heavy oily bromides, while the other hydrocarbons remain unaltered and may be distilled off. The remaining liquid separates, on standing, into three layers, the upper consisting of water with a little hydrobromic acid, the middle of the organic bromides, and the lowest of aqueous hydrobromic acid. The middle layer separated and distilled with alcoholic potash and with sodium, yields the hydrocarbons C^nH^{2n}. The brominated oils obtained from the fractions of the original coal-oil which boiled between 71° and 77° and between 82° and 88°, yielded respectively hexylene boiling at 71° and heptylene boiling at 99° (Greville Williams, Phil. Trans. 1857 [3] 737; Ann. Ch. Pharm. cviii. 384). Heptylene is likewise obtained:—1. By decomposing chloride of heptylene with sodium at a gentle heat.

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The sodium is added by small quantities; the liquid distilled off as soon as the quantity of chloride of sodium becomes so great as to interfere with the action; and the distillate is treated with fresh sodium, the last traces of chlorine being removed by repeatedly rectifying the product over perfectly bright sodium (Limpricht, Ann. Ch. Pharm. ciii. 80). The heptylene which Schorlemmer obtained by treating with sodium the chlorinated compounds produced, in addition to chloride of heptyl, by the action of chlorine on hydride of heptyl (p. 144), probably also resulted from the decomposition of chloride of heptylene.—2. By distilling heptylic alcohol with chloride of zinc: $C^7H^{16}O - H^2O = C^7H^{14}$ (Bouis and Carlet).—3. By heating chloride of heptyl with strong aqueous potash to 180° in sealed tubes for several days (Schorlemmer, p. 144).—Bouis, in 1855, by distilling œnanthol with strong sulphuric acid, obtained a hydrocarbon agreeing in composition with the empirical formula of the olefines, CH^2, and supposed by him to be heptylene; but, as it boiled at 50°, it was probably either a lower member of the series, or a mixture.

Heptylene is a colourless mobile liquid, having a peculiar alliaceous odour; soluble in alcohol. Boils at 95° (Schorlemmer), at 99° (Gr. Williams). Specific gravity 0·718 at 18° (Williams). Vapour-density, obs. = 3·320 (Williams); calc. (2 vol.) = 3·386.

	Calculation.		Limpricht.	Schorlemmer.	
C^7	84	85·71	85·9	85·6	85·66
H^{14}	14	14·29	14·1	14·6	14·00
C^7H^{14}	98	100·00	100·0	100·2	99·66

Bromide of Heptylene. $C^7H^{14}Br^2$.—Obtained by direct combination. It is a liquid, heavier than water, which decomposes on distillation, with blackening and evolution of hydrobromic acid, but volatilises in presence of aqueous vapour, condensing as a nearly colourless liquid having the odour of bromide of ethylene. Gives by analysis 62·26 and 62·23 bromine, the formula requiring 62·01. (Schorlemmer.)

Chloride of Heptylene. $C^7H^{14}Cl^2$.—Produced by the action of pentachloride of phosphorus on œnanthol. When 1 at. œnanthol is gradually allowed to flow into 1 at. pentachloride of phosphorus contained in a tubulated retort, great heat is evolved, and a portion of the resulting oxychloride of phosphorus distils over immediately. As soon as the decomposition of the pentachloride is complete, the liquid is subjected to fractional distillation, the portion which boils above 150° being collected apart as long as it passes over colourless; in the retort there remains a small quantity of a brown thick liquid. The last distillate is washed with water to remove adhering oxychloride of phosphorus; and the oil which floats on the water is shaken up with acid sulphite of sodium, to remove undecomposed œnanthol, then dried with chloride of calcium, and rectified, the portion which boils between 180° and 200° being collected apart: on again rectifying this portion, pure chloride of heptylene passes over at 187°.

Chloride of heptylene is a transparent, colourless, mobile liquid, lighter than water, having a not unpleasant odour, like that of œnanthol. It boils at 191° (corrected). Gives by analysis 48·85 per cent. C, 8·00 H, and 42·05 Cl; the formula requiring 49·4 C, 8·2 H and 42·4 Cl.

When gently heated with *sodium*, it is decomposed with violence, yielding heptylene and chloride of sodium.—Boiled for some time with ethylate of sodium or alcoholic solution of potash, it is resolved into hydrochloric acid, chlorheptylene, $C^7H^{13}Cl$, and a hydrocarbon, probably C^7H^{12}:

$$C^7H^{14}Cl^2 - HCl = C^7H^{13}Cl; \text{ and } C^7H^{14}Cl^2 - 2HCl = C^7H^{12}$$

It is not perceptibly decomposed by acetate of silver, even when continuously boiled with it, or heated to 250° in sealed tubes. (Limpricht, Ann. Ch. Pharm. ciii. 80.)

Chlorheptylene. $C^7H^{13}Cl$.—Obtained by the action of alcoholic potash or ethylate of sodium on chloride of heptylene. A very concentrated alcoholic solution of potash is distilled upwards with chloride of heptylene for a considerable time (the decomposition of 15 grammes of the chloride takes about a week);—or chloride of heptylene and ethylate of sodium are heated together in a sealed tube to 250°. The liquid obtained by either process is diluted with water, which separates impure chlorheptylene; and this crude product is dried by means of chloride of calcium and then subjected to fractional distillation. It begins to boil at 100°, the boiling point slowly rising to 150°, where it remains constant for a while and ultimately rises to 190°. The liquid which passes over below 100° is a hydrocarbon (*see below*); that which distils at 152° is chlorheptylene, and above that temperature the product consists chiefly of undecomposed chloride of heptylene. The complete separation of these liquids can only be effected by repeated rectification.

Chlorheptylene is a liquid resembling chloride of heptylene, having a similar odour, and boiling at 155° (corrected). It gives by analysis 63·5 per cent. C, 9·7 H, and 26·8 Cl, the formula requiring 63·2 C, 9·7 H and 27·1 Cl.

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Sodium remains unaltered in chlorheptylene at ordinary temperatures; but on heating the liquid, a violent action suddenly takes place, chloride of sodium being formed, together with a hydrocarbon, probably C^7H^{12}.—The same hydrocarbon appears to be produced by the action of alcoholic potash on chloride of heptylene (see above). (Limpricht, Ann. Ch. Pharm. cii. 82.)

Hydriodate of Heptylene. $C^7H^{15}I = C^7H^{14}.HI$.—Obtained by heating heptylene with hydriodic acid in sealed tubes to 100° for twelve hours. It closely resembles iodide of heptyl, but boils at about 170°, or 20° lower than the latter. It soon turns brown when exposed to the air. Precipitated by alcoholic nitrate of silver, it yielded a quantity of iodide of silver corresponding to 55·73 per cent. iodine (calc. 56·19); and the filtrate, on being mixed with water, yielded a small quantity of a fragrant liquid, which consisted wholly or in a great part of nitrate of heptylene, $C^7H^{14}.NO^3H$, as on adding an alcoholic solution of potash, and heating gently, an abundant precipitate of nitrate of potassium was formed. (Schorlemmer, Chem. Soc. J. xvi. 220.)

HEPTYL-ETHYLIC ETHER. $C^9H^{20}O = C^7H^{15}.C^2H^5.O$. *Ethyl-œnanthylic ether.* (Wills, Chem. Soc. Qu. J. vi. 312;* Petersen, Ann. Ch. Pharm. cxviii. 75).—Prepared by the mutual action of iodide of ethyl and heptylate of sodium in equivalent proportions:

$$C^7H^{15}NaO + C^2H^5I = NaI + C^7H^{15}.C^2H^5.O.$$

It is a colourless mobile liquid, having a faint odour, and burning with a bright flame insoluble in water, easily soluble in alcohol and ether. Boils at 177° (Wills). Specific gravity = 0·791 at 16°. Vapour-density, obs. = 5·095 (Wills); calc. (2 vol.) = 4·99.

	Calculation.		Wills.	Petersen.
C^9	108	75·00	75·16	74·44
H^{20}	20	13·88	14·44	14·40
O	16	11·12	10·40	11·16
$C^9H^{20}O$	144	100·00	100·00	100·00

HEPTYLIC ALDEHYDE. Syn. with Œnanthol. (*q. v.*)

HEPTYL-METHYLIC ETHER. $C^8H^{18}O = C^7H^{15}.CH^3.O$. *Methyl-œnanthylic ether.* (Wills, Chem. Soc. J. vi. 314.)—Obtained by the action of iodide of methyl on heptylate of sodium. It is a thin mobile liquid, having a strong odour, insoluble in water, easily soluble in alcohol and in ether. Boiling point between 160·5° and 161°. Specific gravity = 0·830 at 16·5°. Vapour-density (obs.) about 4·2; calc. (2 vol.) = 4·5. A specimen not quite pure gave by analysis 73·15 per cent. C, and 14·09 H, the formula requiring 73·85 C and 13·85 H.

HEPTYL-SULPHURIC ACID. $C^7H^{16}SO^4 = \left.\begin{matrix}(SO^2)''\\ C^7H^{15}\\ H\end{matrix}\right\}O^2$. (Petersen, Ann. Ch. Pharm. cxviii. 72.—Bouis and Carlet, *ibid.* cxxiv. 254.)—When 2 pts. of heptylic alcohol are cautiously mixed with 1 pt. sulphuric acid, the mixture being kept cool so as to prevent the formation of sulphurous acid, the liquid ultimately separates into two layers, the upper of which contains heptyl-sulphuric acid. On neutralising it with carbonate, and at last very carefully with hydrate of barium, and concentrating at a gentle heat, heptyl-sulphate of barium separates in small, white, flexible, and generally scaly crystals, having a pearly lustre and bitter taste, very soluble in water, and not precipitated from the aqueous solution by alcohol or ether. The solution decomposes by evaporation unless the temperature be kept very moderate. The dry salt is permanent in the air, but, according to Petersen, begins to decompose at 80°, turning first red, then black, and emitting a very strong odour. According to Bouis and Carlet, on the other hand, it may be heated to 100° without decomposition. According to the mean results of Petersen's analyses, the salt dried over oil of vitriol contains 30·97 per cent. C, 6·19 H, 25·10 Ba, and 11·73 S, agreeing nearly with the formula $2C^7H^{15}BaSO^4.H^2O$, which requires 30·83 C, 5·87 H, 25·14 Ba, 11·74 S, and 26·42 O.

HERAPATHITE. Syn. with Sulphate of Iodoquinine. (See Quinine.)

HERCYNITE. An iron spinel, $FeO.Al^2O^3 = \left.\begin{matrix}Fe''\\ (Al^2)^{vi}\end{matrix}\right\}O^4$. Specific gravity 3·91—3·95. (See Spinel.)

HERDERITE. A very rare mineral, consisting of anhydrous phosphate of aluminium, and phosphate with fluoride of calcium; not yet analysed quantitatively. The crystals are trimetric. Hardness = 5. Specific gravity = 2·985. It resembles apatite in colour and lustre, but is distinguished by its lower specific gravity. Soluble in hydrochloric acid. Melts before the blowpipe to a white bead, with slight intumescence. (Dana, ii. 410.)

* The compound obtained by Wills is described at p. 342, vol. ii. as octyl-ethylic ether; but the balance of evidence is certainly in favour of the supposition that it contains heptyl, not octyl.

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HERMANNITE. See RHODONITE.

HERRERITE. A mineral from Albarradon in Mexico, said by Herrera (J. pr. Chem. viii. 514) to contain 35·58 per cent. tellurium, 12·32 oxide of nickel, and 31·86 carbonic acid. According to Genth, however (*ibid.* lxvi. 475), it is a cupriferous zinc-spar, containing 93·74 per cent. $ZnCO^3$, 3·42 $CuCO^3$, 1·50 $MnCO^3$, 1·48 $CaCO^3$, and 0·29 $MgCO^3$.

HERSCHELITE. A mineral from Aci reale and Aci Castello in Sicily, having the same general formula as lime-harmotome (p. 14), viz. $M^2O.Al^4O^3.4SiO^2 + 5H^2O$, or $M^2(al'')^8Si^4O^{12}.5H^2O$, agreeing also in general formula with gmelinite (ii. 924) excepting in the amount of water, and crystallising, like the latter, in the hexagonal system.

Analyses 1 and 2 are of the mineral from Aci reale, by Damour (Ann. Ch. Phys. [3] xiv. 97); 3, 4, from Aci Castello, by v. Waltershausen (*Vulkanische Gesteine*, p. 260):

	SiO^2	Al^2O^3	Fe^2O^3	CaO	MgO	Na^2O	K^2O	H^2O.
1.	47·39	20·90	. .	0·38	. .	8·33	4·39	17·84 = 99·23
2.	47·46	20·18	. .	0·25	. .	9·35	4·17	17·65 = 99·06
3.	45·89	18·20	1·14	4·84	0·35	5·72	3·72	17·86 = 97·72
4.	47·03	20·21	1·14	4·66	0·49	4·82	2·03	17·86 = 98·24

These analyses lead to the formulæ:

Damour. $\left.\begin{matrix}\frac{2}{3}Na^2O \\ \frac{1}{3}K^2O\end{matrix}\right\} SiO^2.(Al^2O^3.3SiO^2) + 5$ aq.

v. Waltershausen. $\left.\begin{matrix}\frac{4}{5}CaO \\ \frac{1}{5}Na^2 \\ \frac{1}{5}K^2O\end{matrix}\right\} SiO^2.(Al^2O^3.3SiO^2) + 5$ aq.

According to v. Waltershausen, herschelite does not occur at Aci reale.

HESPERIDIN. A substance discovered by Lebreton (J. Pharm. xiv. 377), and contained in many fruits of the genus *Citrus*. It is most readily prepared from unripe Seville oranges, by removing the green rind and the inner part of the fruit, treating the white spongy inner coating with water at a temperature of 25 to 30°; concentrating the liquid, neutralising it with lime-water, and evaporating to a syrup; treating the residue with alcohol of 40 per cent.; then filtering, distilling off the alcohol, and agitating the bitter granular residue with 20 times its weight of distilled vinegar. The liquid on standing deposits hesperidin in warty masses, which may be washed with water and recrystallised from boiling alcohol.

Hesperidin thus purified forms white, silky laminæ, inodorous, and having a bitter taste; sparingly soluble in cold *alcohol*, very soluble in boiling alcohol, insoluble in *ether*; dissolves in 60 pts. of boiling *water*, and separates again on cooling. The solutions are neutral to vegetable colours. It is soluble in warm concentrated *acetic acid*, insoluble in *oils*.

Hesperidin is decomposed by prolonged boiling with *water*, and then floats on the surface like melted wax. It is readily dissolved by caustic *alkalis*. Strong *sulphuric acid* dissolves it with orange-colour, gradually changing to red. Hot *nitric acid* converts it into oxalic acid and a bitter substance. The alcoholic solution is not precipitated by *acetate of lead*, but forms a brown precipitate with *ferric sulphate*.

Wiedemann has described, under the name *hesperidin*, a substance obtained from unripe oranges, differing from that above described in some respects, especially in not being soluble in alcohol.

HESSITE. Telluric silver. (See TELLURIUM.)

HESSONITE. Syn. with ESSONITE (ii. 507).

HETEPOZITE. See HETEROSITE.

HETEROCLINE or *Marceline*. A silicate of manganese occurring at St. Marcel in Piedmont, in oblique rhombic prisms of 128° 16', and containing 10·76 per cent. SiO^2, 85·87 Mn^2O^3, 3·38 Fe^2O^3, 0·61 CaO, and 0·44 K^2O = 100·30. (Evreinoff, Pogg. Ann. xlix. 204.)

HETEROMERITE. An altered form of idocrase from Slatoust in Siberia, containing, according to v. Hauer, 43·29 SiO^2; 23·17 Al^2O^3; 6·10 Fe^2O^3; 23·78 CaO, and 3·05 MgO. Colour light green.

HETEROMORPHISM. The property, sometimes observed in compounds, of crystallising, in different forms, though containing equal numbers of atoms similarly grouped. Such is the case with *sulphate of zinc*, $\left.\begin{matrix}SO^2 \\ Zn''\end{matrix}\right\} O^2 + 7H^2O$, and *ferrous sulphate*, $\left.\begin{matrix}SO^2 \\ Fe''\end{matrix}\right\} O^2 + 7H^2O$; the former crystallising in the trimetric, the latter in the monoclinic

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system. The cause of this difference in the examples just cited is probably that the elements—iron and zinc—are not isomorphous.

HETEROMORPHITE. *Feather ore.*—A sulphantimonite of lead, $Sb^2S^3.2PbS$, which occurs in capillary forms resembling a cobweb; also massive. Specific gravity 5·67 to 5·9. Hardness 1 to 3. Lustre dull metallic. Colour lead-grey to steel-grey, sometimes iridescent. It is found at Wolfberg in the Eastern Hartz; also at Andreasberg and Clausthal; at Freiberg and Schemnitz; in the Anhalt at Pfaffenberg and Meiseberg; and in Tuscany, near Bottino. (Dana, ii. 76.)

HETEROSITE or *Hetepozite.* A hydrated phosphate of iron and manganese, found near Limoges, in dark brown or black masses, containing, according to Dufrénoy's analysis, 41·77 p. c. P^2O^5, 34·89 FeO, 17·57 MnO, 4·40 H^2O, and 0·22 SiO^2 (= 98·85), whence Rammelsberg (*Mineralchemie*, p. 331) deduces the formula $3(5MO.2P^2O^5)$ or $3\left[\begin{matrix}3FeO\\MnO\end{matrix}\right\}2P^2O^5] + 5$ aq.

The same name is applied to an altered triphyllin from Chanteloub, Limoges, of brownish violet colour, specific gravity 3·41, and containing 32·18 p. c. P^2O^5, 31·46 Fe^2O^3, 30·01 Mn^2O^3, and 6·35 water (= 100), whence the formula $5M^2O^3.3P^2O^5 + 5$ aq. (Rammelsberg, *loc. cit.*)

HEULANDITE. See STILBITE.

HEVENE. The least volatile part of the products of the dry distillation of caoutchouc and gutta percha. It is an oily hydrocarbon, of an amber-yellow colour, acrid taste, and specific gravity 0·921 at 21°. Boils at 315°. Mixes in all proportions with alcohol, ether, and oils, both fat and volatile. It rapidly absorbs chlorine, and acquires thereby the consistence of wax. It is partly resinised by sulphuric acid, and then converted into an oil which boils at 228°, and is not attacked by strong acids (Bouchardat, Ann. Ch. Pharm. xxvii. 30). According to Greville Williams, it is probably polymeric with isoprene and caoutchin (ii. 961).

HEXACHLORXYLIN. A product of the action of chlorine on hydrate of phenyl. (See PHENYL.)

HEXACROLEIC ACID. $C^{18}H^{24}O^4$.—An acid polymeric with acrolein, and produced by dropping that liquid into an alcoholic solution of potash. The solution becomes heated to the boiling point; and on addition of an acid, yields hexacroleic acid as a yellow, amorphous, feebly acid substance, soluble in alkalis, alcohol and ether; insoluble in water, easily fusible, but not volatile without decomposition. Most of its salts are insoluble in water. (Claus, Ann. Ch. Pharm. suppl. ii. 117.)

HEXAMETAPHOSPHORIC ACID. See PHOSPHORIC ACID.

HEXAMETHYLENAMINE. $C^6H^{12}N^4 = N\left\{\begin{matrix}N(CH^2)^2\\N(CH^2)^2\\N(CH^2)^2\end{matrix}\right.$.—A volatile crystalline base produced by the action of ammonia on dioxymethylene (Butlerow, Ann. Ch. Pharm. cxv. 322). See METHYLENAMINES.

HEXMETHYLENIC ALCOHOL. See ETHYLENE, HYDRATES OF (ii. 576).

HEXMETHYL-ETHYLENE-DIPHOSPHONIUM. See PHOSPHORUS-BASES.

HEXYL. *Caproyl.* $C^{12}H^{26} = \begin{matrix}C^6H^{13}\\C^6H^{13}\end{matrix}$.—The sixth alcohol-radicle of the series C^nH^{2n+1}. It is produced by the electrolysis of œnanthylic acid:

$$C^7H^{14}O^2 = C^6H^{13} + H + CO^2.$$

To prepare it, a solution of œnanthylate of potassium is decomposed by a voltaic current, and the oil which separates is dried over chloride of calcium, and then distilled with alcoholic potash, which retains œnanthylic acid, while the hexyl passes over with the vapours of alcohol, and may be purified by washing with water and rectification (Brazier and Gossleth, Chem. Soc. J. iii. 210). Wurtz (Ann. Ch. Phys. [3] xliv. 275), by electrolysing a mixture of 100 pts. œnanthylic and 120 pts. valeric acid, neutralising with potash and cooling to 0°, obtained an oil which, after desiccation by chloride of calcium, yielded by fractional distillation, tetryl (C^4H^9), boiling between 100° and 140°, tetryl-hexyl ($C^4H^9.C^6H^{13}$), between 140° and 180°, and a portion boiling between 180° and 220°, consisting chiefly of hexyl.

Hexyl is a colourless oily liquid, of specific gravity 0·7574 at 0°. It boils at 202°, yielding a vapour whose density is 5·983 (Wurtz); calc. (2 vol.) = 5·8979. It is insoluble in water, but soluble in alcohol and ether.

It is not attacked by sulphuric acid, and may be distilled without alteration with moderately concentrated nitric acid; but by repeated distillation with a mixture of sulphuric and nitric acids, it is converted into an acid, probably caproic acid. It is

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scarcely attacked by bromine, even in sunshine. Chlorine attacks it strongly, even in diffused daylight; hydrochloric acid being evolved, and a viscid substance formed, which gives off hydrochloric acid when distilled, and leaves a residue of charcoal. (Brazier and Gossleth.)

The compounds of hexyl were hardly known before the year 1861, the alcohol having been barely identified by Faget, in fusel-oil, in 1854 (Compt. rend. xxxvii. 730). At present, the known sources of hexyl-compounds are: (1) fusel-oil, containing the alcohol; (2) mannite and melampyrin, which, when reduced with hydriodic acid, give iodide of hexyl; and (3) petroleum and coal-tar oil, which contain hydride of hexyl. Whether the hexyl-compounds obtained from (1) and (3) are identical, is still an open question; but, without doubt, those derived from (2) are essentially different from the hexyl-compounds either of fusel-oil or of petroleum. The hexyl-compounds of fusel-oil and of petroleum have been distinguished by the prefix *Alpha*, those of mannite or melampyrin by *Beta*. The former compounds, so far as they have been yet examined, present the very closest analogies to those of the ethyl series; the latter depart in many ways from this standard: thus, they show a great tendency to evolve their olefine during reactions; and their alcohol has too low a boiling point, and when oxidised with dilute chromic acid, does not yield caproic acid, but breaks up into carbonic acid, water, butyric and acetic acids.

The hexyl-compounds derive peculiar interest from their having the same carbon-condensation as the sugars, and from their standing in close relation thereto, as the reaction of hydriodic acid with mannite proves, mannite being, as has long been known, a product of the reduction of glucose (ii. 864).

Berthelot has already remarked upon the peculiar readiness to react shown by tritylene. It is not unworthy of remark, that hexylene, which is paratritylene, likewise displays extraordinary energy.

Acetates of Hexyl.—*α Hexyl-acetate* is prepared by the action of α iodide of hexyl upon acetate of silver. It is a colourless liquid, lighter than water, and boiling at about 145° C. By the action of caustic potash, it has been transformed into an alcohol, boiling at about 150°. (Cahours and Pelouze, Compt. rend. liv. 1245.)

β Hexyl-acetate is prepared by distilling β hexyl-sulphuric acid with a great excess of glacial acetic acid:—

$$\left.\begin{matrix}\beta\,C^6H^{13}\\H\end{matrix}\right\}SO^4 + \left.\begin{matrix}C^2H^3O\\H\end{matrix}\right\}O = \left.\begin{matrix}H\\H\end{matrix}\right\}SO^4 + \left.\begin{matrix}C^2H^3O\\\beta\,C^6H^{13}\end{matrix}\right\}O.$$

It is an oil lighter than water, and very insoluble in water, having a peculiar smell, unlike the usual smell of an acetate of an alcohol-radicle. Boiling point 156°. It distils without decomposition. Digestion at 100°, with an alcoholic solution of potash, transforms it into β hexylic alcohol. Unlike β $C^6H^{13}I$, it yields no hexylene on digestion with alcoholic solution of potash. Sp. gr. at 0° = ·8778 : at 50° = ·8310; therefore expansion-coefficient for 50° = ·0563. It forms a double compound with $NaβC^6H^{13}O$ (beta-hexylate of sodium—the body produced by treating β hexylic alcohol with sodium), which double compound is decomposed by water, giving β hexylic alcohol.

Hexyl-alcohols.—*α Hexyl-alcohol* (caproic alcohol), α $C^6H^{14}O$, was found by Faget, in fusel-oil (1854), but not purified by him. Cahours and Pelouze obtained it from hydride of hexyl, by converting that compound into α iodide of hexyl, thence forming α acetate of hexyl; thence, by means of caustic potash, the alcohol. The α hexyl-alcohol thus prepared boils at about 150°, and smells like amylic alcohol. (Compt. rend. liv. 1245.)

α hexylic alcohol yields caproic acid by oxidation. (Faget.)

β Hexyl-alcohol, β $C^6H^{14}O$.—Prepared by digesting β iodide of hexyl with oxide of silver and water: the β alcohol is then formed, together with β hexylic ether, and β hexylene. Or better, by shaking up β hexylene with sulphuric acid (previously diluted with one-third its volume of water), by which means β hexyl-sulphuric acid is produced, and this, distilled with a large excess of water, yields β hexyl-alcohol. It is a viscid liquid, having a refreshing, pleasant smell, very unlike that of amylic alcohol; boils at 137°, under bar. pressure of 755·5 millimetres. Specific gravity at 0° = 0·8327; at 16° = 0·8209; at 99° = 0·7482. It therefore expands somewhat rapidly.

Concentrated *sulphuric acid* converts it into para-hexylene, even at 0°, and does not form any hexyl-sulphuric acid, even after standing for some time. More dilute acid (strength about 87 per cent. SO^4H^2) forms β hexyl-sulphuric acid, which is capable of forming salts. *Acid chromate of potassium* and dilute sulphuric acid convert it into an aldehyde, which has no tendency to take up oxygen from the air, and when further oxidised with the same oxidising agent, yields, not caproic acid, but carbonic acid, water, butyric and acetic acids. The β variety of the alcohol has not been converted into the α variety; on the contrary, there is every reason to believe that the two bodies are radically different. (Wanklyn and Erlenmeyer, Chem. Soc. J. xvi. 221.)

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Hexyl-aldehydes.—*α Hexyl-aldehyde*, α $C^6H^{12}O$.—Unknown: it might perhaps be obtained by oxidation from the α alcohol of fusel-oil, or of that derived from the hexyl-hydride found in petroleum.

β Hexyl-aldehyde, β $C^6H^{12}O$.—Obtained by oxidising the corresponding alcohol with acid chromate of potassium and dilute sulphuric acid. It is a colourless limpid liquid of fragrant, penetrating odour; boils at 127° (bar. = 761·2 millimetres). Specific gravity at 0° = 0·8298, at 50° = 0·7846: coefficient of expansion between 0° and 50° = 0·0576. It forms a solid compound with acid sulphite of sodium; does not reduce ammonio-nitrate of silver; does not take up oxygen from the air. 100 parts of water dissolve about one part of β hexyl-aldehyde. When treated with *acid chromate of potassium* and dilute sulphuric acid, it yields no caproic acid, but butyric, acetic, and carbonic acids, and water (Wanklyn and Erlenmeyer, Chem. Soc. J. xvi. 307). A consideration of these reactions of β hexylic aldehyde leads to the conclusion that it is an acetone; for whilst the aldehydes take up oxygen from the air and yield by oxidation the corresponding acid, the acetones do not take up oxygen from the air, and yield lower acids (when oxidation is brought about).

This view of the case becomes increasingly probable when the history of acetic acetone, lately brought to light by Lieben, is considered. Acetone is reduced by hydrogen to tritylic alcohol; but the tritylic alcohol thus formed yields by oxidation, not propionic aldehyde, but common acetone.

β Hexyl-aldehyde will probably turn out to be either methyl-valeryl, $\left.\begin{matrix}CH^3\\C^5H^9O\end{matrix}\right\}$, or ethyl-butyryl, $\left.\begin{matrix}C^2H^5\\C^4H^7O\end{matrix}\right\}$.

Chlorides of Hexyl.—*α Hexyl-chloride*, α $C^6H^{13}Cl$, is obtained by Pelouze and Cahours, by the action of chlorine upon the hydride of hexyl existing in American petroleum. In addition to the α chloride of hexyl, further substitution-products are obtained. α Chloride of hexyl decomposes an alcoholic solution of *monosulphide of potassium*, giving α sulphide of hexyl, α $(C^6H^{13})^2S$, boiling at 230°. With *sulphydrate of potassium*, it gives hexyl-mercaptan: boiling point 145° to 148°. With *cyanide of potassium*, it seems to give α cyanide of hexyl. (Compt. rend. x. 1241, *et seq.*)

β Hexyl-chloride is obtained by saturating the corresponding alcohol with dry hydrochloric acid, and heating in the water-bath under pressure. It is an oily liquid, lighter than water, boiling at about 120°, and yielding hexylene when digested at 100° with alcoholic solution of potash.

Hydrides of Hexyl.—*α Hexyl-hydride*, α C^6H^{14}, was found by Greville Williams in the products of the distillation of Boghead coal, and called by him (originally) propyl (with which it is isomeric); in 1862 he came to the conclusion that his propyl was hexyl-hydride (Chem. Soc. J. xv. 130). Pelouze and Cahours found the same substance in American petroleum (Compt. rend. liv. 1241), and obtained a chlorine substitution-product from it, which reacted as chloride of hexyl should do. From the chloride was indirectly obtained an alcohol (p. 152) boiling at about 150°, and like amyl-alcohol in odour. Schorlemmer obtained the hydride also from the products of distillation of Cannel coal. Its boiling point is 68°. Density of the liquid = 0·6745 at 18° (Williams); 0·669 at 16° (Pelouze and Cahours); 0·678 at 15·5° (Schorlemmer). The vapour-density corresponds closely with the formula C^6H^{14}. It is a colourless mobile liquid, having a fragrant odour. Chemically, like all bodies of its class, it is very inactive. Neither sulphuric acid nor nitric acid attacks it; chlorine and bromine only with difficulty. In the arts, a mixture of α hydride of hexyl with other hydrides goes by the name of *turpentine substitute*.

β Hexyl-hydride, β C^6H^{14}, is obtained indirectly from mannite. It may be prepared by digesting zinc with β iodide of hexyl and water or alcohol; or by exposing mercury and the iodide to the action of sunlight. In the latter case the reaction is:

$$Hhg + 2C^6H^{13}I = HhgI^2 + C^6H^{12} + C^6H^{14}.$$

In the former case hexylene also accompanies the hydride. In order to remove the hexylene, it is well to shake up with sulphuric acid, which enters into combination with the hexylene.

In smell, boiling point, and outward appearance, the β hydride resembles the α hydride very closely. In specific gravity, however, it appears to differ from the α compound, being lighter. At 16·5° its specific gravity does not exceed 0·6645. Its derivatives are probably quite distinct from those of the α hydride.

Iodides of Hexyl.—*α Hexyl-iodide*, α $C^6H^{13}I$, is obtained by Pelouze and Cahours from hydride of hexyl existing in American petroleum. It boils at 172° to 175° (being of higher boiling point than the β iodide), and smells like iodide of amyl. It is acted upon by light. It reacts with a variety of salts, forming ethers. The

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alcohol which is indirectly obtained from it boils at 150°, and is believed by Pelouze and Cahours to be identical with Faget's alcohol extracted from fusel-oil (Compt. rend. liv. 1241, *et. seq.*) Wurtz has also obtained a hexyl-iodide by acting with hydriodic acid upon a variety of hexylene which seems to be distinct from the β hexylene of mannite.

β Hexyl-iodide is prepared by boiling mannite with a great excess of the strongest aqueous solution of hydriodic acid in a stream of carbonic anhydride (24 grms. mannite to 300 cub. cent. of acid, boiling at 126° C.); phosphorus may be added to the boiling liquid with great advantage. The iodide of hexyl appears in the form of an oily distillate, which should be freed from iodine and purified by distilling it in contact with water. When the operation is properly performed, very nearly the theoretical quantity of perfectly pure iodide of hexyl is obtained. The change which takes place is represented by:

$$\underset{\text{Mannite.}}{C^6H^8(HO)^6} + 11\,HI = \underset{\text{Iod. hexyl.}}{C^6H^{13}I} + 6H^2O + I^{10}.$$

Melampyrin (ii. 349) may be substituted for mannite in the above process; but the yield is not so good. The β iodide may also be prepared by digesting β hexylene with hydriodic acid.

β Iodide of hexyl is a colourless liquid, not to be distinguished by the smell from iodide of amyl. Specific gravity at 0° = 1·4447; at 50° = 1·3812; its co-efficient of expansion between 0° and 50° is 0·0460. The boiling point at 752 millimetres = 167·5° C. It is only very slightly decomposed by distillation, and is, on the whole, a very stable compound.

The almost invariable product of the reaction of this iodide is hexylene. With alcoholic solution of potash, it has given very nearly the theoretical quantity of hexylene:

$$\beta\,C^6H^{13}I + KHO = \beta\,C^6H^{12} + H^2O + KI.$$

With *oxide of silver* and *water*, *acetate of lead*, *mercury*, *sodium*, *oxalate of silver*, *zinc and water*, or *zinc and alcohol*, and finally, when heated to 190° with *water* alone, it invariably yields considerable quantities of hexylene, other products being formed at the same time, according to the reagent employed.

Bromine acts with great violence, replacing the equivalent of iodine in β iodide of hexyl.

β Hexyl-oxide, $\beta\,\left.\begin{matrix}C^6H^{13}\\C^6H^{13}\end{matrix}\right\}O$ is formed, together with the olefine and alcohol, when moist oxide of silver acts upon the corresponding iodide:

$$Ag^2O + 2\,\beta\,C^6H^{13}I = 2AgI + \beta\,\left.\begin{matrix}C^6H^{13}\\C^6H^{13}\end{matrix}\right\}O.$$

It is a thick, slightly yellow liquid, not miscible with water, and of a faint penetrating smell. Boils constantly between 203·5° and 208·5°, with the barometer at 751 millimetres.

Hexyl-sulphuric acids. — α *Hexyl-sulphuric acid*, $\alpha\,\left.\begin{matrix}C^6H^{13}\\H\end{matrix}\right\}SO^4$, is little known.

β Hexyl-sulphuric acid is obtained by the action of sulphuric acid (diluted with about one-third of its volume of water) either on β hexylene, or on β hexyl-alcohol. It is partially decomposed by dilution with water, and gives off β hexyl-alcohol. Salts of this acid have been obtained.

β Sulphydrate of Hexyl, or *β Hexyl-mercaptan*, is obtained by digesting the β iodide with a concentrated alcoholic solution of sulphydrate of potassium:

$$\beta\,C^6H^{13}I + KHS = \beta\,\left.\begin{matrix}C^6H^{13}\\H\end{matrix}\right\}S + KI.$$

On adding water to the product of the reaction, the mercaptan separates as a clear, colourless, mobile liquid, not miscible with water and lighter than water. β Hexyl-mercaptan is formed *in the theoretical quantity* in this operation. As was mentioned above, an alcoholic solution of hydrate of potassium transforms β iodide of hexyl almost completely into hexylene and water; sulphydrate of potassium, on the other hand, transforms the iodide into β sulphydrate of hexyl. When an alcoholic solution of *sulphide of potassium* is used, there is also no formation of hexylene, but of a β sulphide instead, so that the sulphur-compounds of the β series are much more stable than the corresponding oxygen-compounds.

It is further noteworthy that β hexyl-mercaptan boils at 142° under a bar. pressure of 760 millimetres—being the point at which the α mercaptan ought to boil.

β Hexyl-mercaptan has the kind of smell characteristic of a mercaptan, only it seems not to be so persistent as the smell of common mercaptan. It acts upon oxide of mer-

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cury with energy. Sodium attacks it, with evolution of a gas and formation of a white residue; no doubt the reaction is of the usual kind:

$$\left.\begin{matrix}\beta\ C^6H^{12}\\ H\end{matrix}\right\}S + Na = \left.\begin{matrix}\beta\ C^6H^{12}\\ Na\end{matrix}\right\}S + H.$$

Very curiously, caustic potash, both solid and in aqueous solution, also attacks this mercaptan; and, still more curiously, a heat of 100° C. decomposes the compound formed with aqueous potash, occasioning separation of the mercaptan, which, however, recombines on cooling. J. A. W.

HEXYLENE. C^6H^{12}.—Of this hydrocarbon there are also two modifications.

α Hexylene. It is doubtful whether Fremy's hydrocarbon, boiling at 55° and obtained by the distillation of hydroleic and metoleic acids, was hexylene. Greville Williams obtained hexylene from the products of the distillation of Boghead coal. It boiled at 71° (Phil. Trans. 1847). Wurtz seems to have obtained a variety of hexylene from fusel-oil.

β Hexylene is formed by the reaction of the corresponding iodide with most reagents. It is best prepared by the action of the iodide upon alcoholic solution of caustic potash, at 100°. In preparing it, the precaution should be taken to distil the alcoholic solution of hexylene from the iodide of potassium produced during the reaction, and to digest the distillate with fresh potash. The alcohol is subsequently removed by washing.

β Hexylene is a very mobile liquid, lighter than, and not miscible with, water. Boiling point 68° to 70°. Its odour is very unpleasant, just like that of amylene. Vapour-density, by experiment, 2·88 and 2·97 (theory requires 2·9022). It combines with *bromine* with great violence, forming $C^6H^{12}Br^2$. With concentrated *sulphuric acid* it gives parahexylene. With sulphuric acid diluted with about one-third its volume of water, it gives β hexyl-sulphuric acid. β Hexylene seems to be a lighter liquid than α hexylene. J. A. W.

HIPPARAFFIN. C^9H^7NO.—A product of the oxidation of hippuric acid, discovered by Schwarz (Ann. Ch. Pharm. lxxv. 201), further investigated by J. Maier, (*ibid.* cxxvii. 161), who has shown that hipparin is formed at the same time. To prepare it, hippuric acid is stirred up to a paste with dilute sulphuric acid, then mixed with peroxide of lead, and left to stand at a gentle heat for 12 to 24 hours. The mass is then washed with cold water; the residue exhausted with alcohol; the alcoholic solution evaporated; the residue washed with carbonate of soda to remove benzoic and undecomposed hippuric acid; and the residue boiled with water, which leaves hipparaffin undissolved and deposits hipparin on cooling. (Maier.)

Hipparaffin crystallises from hot alcohol in extremely soft slender needles, having a silky lustre and arranged in thick interlaced tufts. It has neither taste nor odour; dissolves sparingly in hot, and is quite insoluble in cold *water*, which does not even wet it; the solubility is not increased by addition of sulphuric acid, hydrochloric acid, ammonia or potash. It dissolves in strong *sulphuric acid*, and is precipitated by water without much alteration (Schwarz). Dissolves easily in strong sulphuric and nitric acid, and is not precipitated from either solution by water (Maier). It dissolves readily in boiling *alcohol*, and very readily in *ether*. It melts at 200° (Schwarz), 210° (Maier), solidifying in the crystalline form as it cools. At a higher temperature part of it distils without alteration, the residue turning black (Schwarz); a small quantity sublimes in slender needles even below 100°. (Maier.)

Hipparaffin burns with a bright smoky flame, leaving a small quantity of easily combustible charcoal. It is not decomposed by solution of *iodine*, or by *hydrochloric acid and chlorate of potassium*, or by aqueous *chromic acid*. It is but partially decomposed by fusion with *hydrate of potassium;* but on igniting it with *potash-lime*, benzene is produced, and the whole of the nitrogen is given off in the form of ammonia (Schwarz). Heated to 200°—220° in a stream of *hydrochloric acid gas*, it gives off a colourless oil, which solidifies in the crystalline form. *Fuming nitric acid* dissolves it, with evolution of gas, and the solution, concentrated after neutralisation with soda, yields a precipitate of benzoic acid. Heated with *peroxide of lead* and dilute sulphuric acid, it gives off all its carbon in the form of carbonic anhydride. (Schwarz.)

HIPPARIN. $C^9H^9NO^2$. (J. Maier, *loc. cit.*)—The preparation is given in the preceding article. Hipparin crystallises in large silky needles united in barrel-shaped groups. Melts at 45·7°; solidifies at about 20°; burns with a bright flame; dissolves easily in alcohol, ether, and boiling water.

HIPPOPHAË RHAMNOIDES. The *Sea Buckthorn.*—This plant contains a yellow colouring matter which appears to be identical with quercitrin. It is obtained by exhausting the berries, after they have been well boiled in water and dried, with hot alcohol; mixing the hot filtered liquid with basic acetate of lead; decomposing

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the precipitate with sulphydric acid; heating the whole; filtering when cold; and treating the precipitated sulphide of lead with hot alcohol. The colouring matter then dissolves, and remains on evaporation, as a brown-red brittle mass still retaining a little fat, from which it may be purified by treatment with ether, absolute alcohol, &c. It is then obtained as a yellow mass containing rudimentary crystals. The berries likewise contain oxalic and malic acids, a peculiar fat, &c., which are extracted by boiling them with water. (Bolley, Dingl. pol. J. clxii. 143; Jahresber. 1861, p. 708.)

HIPPURAMIDE. $C^9H^{10}N^2O^2 = \left.\begin{matrix} C^7H^5O \\ (C^2H^2O)'' \\ H^3 \end{matrix}\right\} N^2$.—This amide is produced by the prolonged action of ammonia on an alcoholic solution of hippurate of methyl, and remains when the solution is evaporated. It dissolves in 100 pts. water at ordinary temperatures, in 80 pts. wood-spirit, and 50 pts. alcohol; sparingly soluble in ether. By alkalis at the boiling heat it is resolved into ammonia and hippuric acid. (Jacquemin and Schlagdenhauffen, Compt. rend. xlv. 1011.)

HIPPURIC ACID. $C^9H^9NO^3 = \left.\begin{matrix} H \\ C^7H^5O \\ (C^2H^2O)'' \\ H \end{matrix}\right\} \begin{matrix} N^* \\ \\ \\ O \end{matrix}$. (Gm. xii. 69; Gerh. iii. 242).—This acid exists in the urine of herbivorous animals, and in smaller quantity in that of man. Rouelle, towards the end of the last century, first observed that the urine of horses contained an acid bearing considerable resemblance to benzoic acid, and the observation was afterwards confirmed by Fourcroy and Vauquelin, who separated the acid by addition of hydrochloric acid; but its real nature and separate identity were first established by Liebig, in 1830 (Ann. Ch. Pharm. xii. 20). The urine of cows and horses does in fact contain, sometimes hippuric and sometimes benzoic acid, the former acid being easily converted into the latter by oxidation; and this change often taking place within the animal organism. When horses are kept in the stable, or only lightly worked, their urine contains hippuric acid; but when they are put to hard work, it contains benzoic acid.

Cows' urine, according to Boussingault, contains about 1·3 per cent. of hippuric acid; in that of horses, the maximum amount is about 0·38 per cent.; that of swine does not appear to contain hippuric acid; that of the camel and elephant yields a considerable quantity.

From the experiments of Henneberg, Stohmann, and Rautenberg (Ann. Ch. Pharm. cxxiv. 181; Rép. Chim. pure 1863, p. 223; Jahresber. 1862, p. 541) it appears that the urine of oxen contains a maximum quantity of hippuric acid (2·1 to 2·7 per cent.) when the animals are fed on oat- and wheat-straw with a small admixture of beans. The straw and dried herb of leguminous plants reduced the amount to 0·4 per cent. With the hay of graminaceous plants intermediate results were obtained. The addition of a certain quantity of beans, starch, sugar, or oil, diminished the proportion of hippuric acid, and increased that of urea.

In human urine, the proportion of hippuric acid is but small under normal conditions, and about equal to that of uric acid (Liebig; Bence Jones); in certain diseases, as in diabetes, according to Lehmann, the amount is considerably greater; a vegetable diet likewise increases it. In the urine of a healthy man living on a mixed diet, Bence Jones (Chem. Soc. J. xv. 81) found, by Liebig's method of estimation (p. 158), from 0·03 to 0·04 per cent. hippuric acid; Thudichum (*loc. cit.* xvii. 55) found the same quantity under similar circumstances; but the amount was largely increased by eating greengages. Weismann (J. pr. Chem. lxxiv. 106; Jahresber. 1858, p. 572) and Wreden (J. pr. Chem. lxxvii. 146; Jahresber. 1859, p. 700) found much larger quantities; but the former appears to have operated on too small a quantity of urine, and the latter adopted a defective method of analysis (p. 159).

Formation.—1. By heating glycocine in a sealed tube with benzoic acid:

$$C^2H^5NO^2 + C^7H^6O^2 = C^9H^9NO^3 + H^2O;$$

also by heating the zinc-salt of glycocine with chloride of benzoyl to 120° in a sealed tube, or by simply leaving the two compounds in contact for some time:

$$C^4H^6ZnN^2O^4 + 2C^7H^5OCl = 2C^9H^9NO^3 + ZnCl^2.$$

This formation of hippuric from benzoic acid likewise takes place when the latter acid is injected into the blood of a living animal, together with glycocine or glycocholate of sodium, or bile. When about 2 grms. of benzoic acid, and 30 c.c. of bile free from mucus were injected into the blood of a dog or cat, the urine was found to contain a considerable quantity of hippuric, but no benzoic acid; with a larger proportion of

* On the rational formula of hippuric acid, see FORMULÆ (ii. 697).

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benzoic acid, the excess passed into the urine together with the hippuric acid. Benzoic acid injected into the circulation alone, is not converted into hippuric acid. (Kühne and Hallwachs, Jahresber. 1859, p. 638.)

2. Benzoic acid is likewise converted into hippuric acid in the animal organism when introduced into the alimentary canal, hippuric acid being found in the urine after benzoic acid has been swallowed. Marchand, after taking 30 grains of benzoic acid, found 39·2 grs. of hippuric acid in his urine (by calculation, it should have been 44 grs.). Similar observations have been made by Al. Ure (J. Pharm. xxvii. 646), Keller (Ann. Ch. Pharm. xliii. 198), and Garrod (Phil. Mag. [3] xx. 501).

3. Quinic acid is also converted in the animal organism into hippuric acid (probably first into benzoic acid). When 8 grms. of quinate of calcium were swallowed over night, the morning urine was found to contain 2 grms. of hippuric acid. (Lautemann, Ann. Ch. Pharm. cxxv. 9.)

Preparation from horses' or cows' urine.—Hippuric acid exists in the urine in combination with ammonia. To obtain it, the fresh urine of cows or of horses which have been kept at rest, is concentrated by evaporation to $\frac{1}{6}$ or $\frac{1}{8}$ of its bulk and supersaturated with hydrochloric acid; it then, after a while, deposits a yellowish-brown precipitate of hippuric acid.

The evaporation of the urine, which is tedious, may be obviated by mixing it with a considerable excess of hydrochloric acid, the solubility of the hippuric acid being thereby greatly diminished. 100 pts. of cows' urine mixed with 2 or 3 pts. of crude hydrochloric acid soon deposits hippuric acid (Riley, Chem. Soc. Qu. J. v. 97). Another mode of expediting the process is to mix the fresh urine with milk of lime, boil for a few minutes and strain; then evaporate the solution of hippurate of calcium to $\frac{1}{8}$ or $\frac{1}{12}$ of its bulk, according to the previous concentration; and supersaturate with hydrochloric acid. (Gregory, Ann. Ch. Pharm. lviii. 125.)

The acid obtained as above has a brownish colour and disagreeable urinous odour, and requires further purification. This may be effected in several ways: 1. Schwarz (Ann. Ch. Pharm. liv. 29) boils the crude acid with milk of lime, which removes the greater part of the fibrin with which it is contaminated; precipitates the filtrate with carbonate of sodium, then boils and filters again, and mixes the filtrate with solution of chloride of calcium, the carbonate of calcium thereby precipitated carrying down the colouring matter; then filters a third time, and precipitates with hydrochloric acid. The hippuric acid thus purified is quite colourless.—2. The crude acid, mixed with 10 pts. of boiling water and excess of milk of lime, is submitted to pressure; the expressed liquid is mixed with solution of alum till it no longer exhibits an alkaline reaction, and left to cool to 40°; carbonate of sodium is then added as long as a precipitate continues to form; and the liquid is again separated by straining and pressure, and precipitated by hydrochloric acid: the hippuric acid thus obtained is washed with cold water, pressed and dissolved in boiling water, and the solution is mixed with blood-charcoal (1 oz. to a lb. of the acid), filtered through paper while still at the boiling heat, and left to crystallise (Bensch, Ann. Ch. Pharm. lviii. 267).—3. Löwe prepares hippuric acid by mixing fresh horse-urine with excess of sulphate of zinc; evaporating the liquid together with the precipitate to $\frac{1}{6}$ or $\frac{1}{8}$ of its bulk; filtering quickly; washing the precipitate with a small quantity of hot water; and decomposing the hippurate of zinc in the filtrate with dilute sulphuric or hydrochloric acid. Hippuric acid then separates in the form of a white magma, which may be washed with cold water, pressed between paper, and recrystallised from boiling water. The addition of sulphate of zinc to the urine preserves it from putrefaction, and enables the experimenter to wait till a considerable quantity is collected.

Properties.—Hippuric acid forms colourless transparent prisms, having an unctuous adamantine lustre, and often of considerable size. The crystals belong to the trimetric system. Ordinary combination, $\infty P . \breve{P}\infty . \breve{P}\infty$. with the modifying faces $\infty\breve{P}\infty$ and $\infty\breve{P}\infty$. Ratio of the axes, $a : b : c = 0{\cdot}9742 : 1{\cdot}1606 : 1$. Inclination of the faces: $\infty P : \infty P$ in the brachydiagonal principal section $= 99° 59'$; $\breve{P}\infty : \breve{P}\infty = 98° 30'$; $\breve{P}\infty : \breve{P}\infty$ in the macrodiagonal principal section $= 88° 30'$. Cleavage tolerably easy, parallel to oP. Specific gravity $= 1{\cdot}308$. Hippuric acid melts at a gentle heat, and solidifies in a crystalline mass on cooling. It has a slightly bitter taste, and reddens litmus strongly. It is sparingly soluble in cold *water*, 1 pt. of the crystals requiring 600 pts. of water at 0°. Boiling water and *alcohol* dissolve it readily; *ether* scarcely at all. Hippuric acid likewise dissolves, but very sparingly, in water containing *hydrochloric acid*. It dissolves with the greatest facility in water containing ordinary *phosphate of sodium*, in such quantity indeed as to change the reaction of the solution from alkaline to acid—a property which is also possessed by uric acid. This, according to Liebig, is the cause of the acid reaction exhibited by the urine of man and other animals in the recent state.

Decompositions.—1. Hippuric acid boils at 240°, yielding a crystalline product, con-

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sisting in great part of benzoic acid and benzonitrile (cyanide of phenyl); a strong odour of hydrocyanic acid is likewise evolved, and a considerable quantity of charcoal remains in the retort. Dry hippuric acid, heated in a retort with dry chloride of zinc and quartz-sand, yields benzonitrile, carbonic anhydride, and charcoal (Gössmann, Ann. Ch. Pharm. c. 69):

$$2C^9H^9NO^3 - 4H^2O = 2C^7H^5N + CO^2 + C^3.$$

2. Hippuric acid in alkaline solution is slowly oxidised by *ozone*, with formation of carbonic acid and a small quantity of formic acid (Gorup-Besanez, Ann. Ch. Pharm. cxxv. 217).—3. Pure hippuric acid is not altered by boiling with *water*; but when horse-urine is quickly evaporated, ammonia is given off, and the hippuric acid contained in it is converted into benzoic acid. Cows' urine does not yield benzoic acid when boiled.—4. Hippuric acid dissolves in strong *hydrochloric acid* at the boiling heat, and on continuing the ebullition, it is resolved into benzoic acid and glycocine:

$$\underset{\text{Hippuric acid.}}{C^9H^9NO^3} + H^2O = \underset{\text{Glycocine.}}{C^2H^5NO^2} + \underset{\text{Benzoic acid.}}{C^7H^6O^2}.$$

The same decomposition is effected by boiling dilute *sulphuric acid*, by *nitric*, and even by *oxalic acid*.—5. Hippuric acid, boiled for half-an-hour with caustic *potash* or *soda*, is converted into glycocine and an alkaline benzoate. It is not decomposed by boiling with milk of lime.—6. The resolution of hippuric acid into benzoic acid and glycocine is likewise effected by the action of a *ferment* in presence of an alkali (Buchner, Ann. Ch. Pharm. lxxviii. 203).—7. By the action of *nascent hydrogen*, it appears to be resolved into hydride of benzoyl and glycocine (Erlenmeyer, Zeitschr. Ch. Pharm. 1861, p. 548).—8. *Nitrous acid* converts hippuric acid into benzoglycollic acid, with evolution of nitrogen gas:

$$2C^9H^9NO^3 + N^2O^3 = 2C^9H^8O^4 + H^2O + N^4.$$

This decomposition takes place when nitric oxide is passed into a solution of hippuric acid in nitric acid.—9. A cold mixture of strong *sulphuric acid* and fuming *nitric acid* converts hippuric acid into nitrohippuric acid. With *sulphuric anhydride*, it unites directly, forming sulphohippuric acid, $C^9H^9NSO^6$.—10. An aqueous solution of hippuric acid is not decomposed by *chlorine* gas; but on boiling it with a large excess of *bleaching powder*, decomposition takes place (Liebig). When chlorine is passed into a solution of hippuric acid in rather dilute potash, nitrogen is evolved, and benzoglycollic acid is produced (Gössmann):

$$C^9H^9NO^3 + 3KHO + Cl^2 = C^9H^8O^4 + 2H^2O + 3KCl + N.$$

11. By mixing it with *hydrochloric acid*, and adding *chlorate of potassium* by small portions, it is converted into a mixture of monochlorohippuric acid, $C^9H^8ClNO^3$, and dichlorohippuric acid, $C^9H^7Cl^2NO^3$ (R. Otto, Ann. Ch. Pharm. cxxii. 129).—12. When hippuric acid is gently heated with 1 at. *pentachloride of phosphorus*, oxychloride of phosphorus and hydrochloric acid are given off, and a brown residue is left, soluble in alcohol and in ammonia, and precipitated therefrom in the resinous state by hydrochloric acid; but on distilling 1 at. hippuric acid with 2 at. pentachloride of phosphorus, the products obtained are oxychloride of phosphorus, chloride of benzoyl, and two chlorinated compounds, $C^9H^6ClNO^2$, and $C^9H^5Cl^2NO^2$, differing from mono- and dichlorohippuric acids respectively by 1 at. H^2O (Schwanert, see p. 161).—13. When hippuric acid is boiled with *peroxide of manganese* and very dilute sulphuric acid, a large quantity of carbonic anhydride is evolved, benzoic acid separates on cooling, and the liquid is found to contain sulphate of ammonium.—14. Hippuric acid, boiled with *peroxide of lead* and water, yields benzamide, water, and carbonic anhydride (Fehling):

$$C^9H^9NO^3 + 3O = C^7H^7NO + H^2O + 2CO^2.$$

When hippuric acid is heated with peroxide of lead and excess of nitric or sulphuric acid, the products formed are carbonic anhydride and hipparaffin (p. 154); but when it is boiled with water and peroxide of lead, and sulphuric acid added in quantity only sufficient to decompose the resulting hippurate of lead, the only product obtained is benzamide (Schwartz).—15. Hippuric acid, gently heated with excess of caustic *baryta*, yields a liquid which smells of benzene (no ammonia is evolved), is converted into crystalline scales by contact with hydrochloric acid, and, when distilled, yields pure benzene (Gerhardt). This liquid is perhaps benzonitrile.

Estimation of Hippuric acid in urine.—1. The urine is evaporated to a syrupy consistence over a water-bath; hydrochloric acid is added; and the hippuric acid is extracted by treating the precipitate four or five times with ether (Liebig, Ann. Ch. Pharm. l. 170). According to Bence Jones (Chem. Soc. J. xv. 81), this method gives exact results, provided sufficient urine is taken (about 400 c. c.), and a sufficient quantity of ether is used. Thudichum (Chem. Soc. J. xvii. 55) evaporates the urine to

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a stiff syrup, pours it into a bottle while yet warm, taking up the last residues with the necessary amount of hydrochloric acid; and shakes up the whole briskly with large quantities of dry ether. The ethereal solution is then distilled, the reddish yellow residue mixed with a little water, and allowed to crystallise; and the crystals of hippuric acid thus obtained are washed with water till the washings are colourless, then dried by pressure between blotting paper, afterwards by placing them over sulphuric acid, and finally at 100° in a water-oven. (See also Weismann, J. pr. Chem. lxxiv. 106; Jahresber. 1857, p. 637.)

2. Wreden (J. pr. Chem. lxxvii. 446; Jahresber. 1859, p. 700) estimates hippuric acid in urine by means of a standard solution of ferric chloride. The liquid is first neutralised and freed from phosphoric acid by means of baryta-water, and the iron solution is added till it no longer forms a precipitate, and a drop of the filtered solution produces a blue colour on a piece of filtering paper moistened with ferrocyanide of potassium. The amount of hippuric acid found in human urine by this method of estimation (average 0·38 per cent.) is much higher than that determined by Liebig's method (p. 156); and, according to Henneberg, Stohmann, and Rautenberg (Ann. Ch. Pharm. cxxiv. 181), the results are vitiated by the fact that a perfectly neutral solution of ferric chloride is decomposed by paper-fibre to such an extent, that paper soaked in a solution of yellow prussiate will not indicate the presence of a small quantity of iron; also, because the termination of the reaction cannot be distinctly perceived. Better results are obtained with ferric nitrate, after the urine has been freed from colouring matter and other bodies by nitrate of lead; but even in this case the process is sometimes rendered uncertain by the presence of other substances which exert a reducing action on the ferric oxide. Altogether, the mode of estimation by means of hydrochloric acid and ether appears to give the best results.

Hippurates. Hippuric acid is monobasic, the general formula of its salts being $C^9H^8MNO^3$. Most metallic oxides dissolve readily in the acid. The hippurates of potassium, sodium, ammonium and magnesium are very soluble and difficult to crystallise; their solutions form a cream-coloured precipitate with ferric salts, and white curdy precipitates with nitrate of silver and mercurous nitrate. A characteristic reaction of the hippurates is, that when fused with excess of potash or lime, they give off ammonia and yield benzene by distillation. Mineral acids decompose them, separating the hippuric acid.

Hippurate of Ammonium.—The *neutral salt* does not appear to exist. *An acid* salt, $C^9H^7(NH^4)NO^3.C^9H^9NO^3.H^2O$, is produced even when hippuric acid is mixed with excess of ammonia. It crystallises by concentration in square-based prisms with 4-sided summits. It dissolves in small quantities of water and alcohol, sparingly in ether, and performs gyratory movements when thrown on the surface of water.

Hippurate of Barium, $C^{18}H^{16}Ba''N^2O^6 + H^2O$, forms prisms with rectangular base; soluble in water. It unites with benzoate of barium, forming a salt containing $C^{18}H^{16}Ba''NO^6.C^{14}H^{10}Ba''O^4 + 5H^2O$.

Hippurate of Calcium, $C^{18}H^{16}Ca''N^2O^6 + 3H^2O$, crystallises sometimes in rectangular prisms, sometimes in laminæ. Specific gravity 1·318. It is soluble in 18 pts. of cold and 6 pts. of hot water.

Hippurate of Cobalt, $C^{18}H^{16}Co''N^2O^6.5H^2O$, forms rose-coloured needles or nodules, which give off their water at 100°.

Hippurate of Copper, $C^{18}H^{16}Cu''N^2O^6 + 3H^2O$, obtained by concentrating a mixture of sulphate of copper and hippurate of potassium, forms oblique rhomboïdal prisms of an azure-blue colour, which turn green and give off their water of crystallisation when heated on the water-bath.

Hippurate of Iron (ferricum) is precipitated on mixing the concentrated solutions of hippurate of potassium and ferric chloride.

Hippurate of Lead, $C^{18}H^{16}Pb''N^2O^6 + 2H^2O$ and $3H^2O$, is obtained by precipitating a cold solution of neutral acetate of lead with hippurate of potassium, as a curdy precipitate which dissolves but slowly in boiling water. If the boiling solution is well diluted, the salt is deposited in silky needles (containing 1 at. water) grouped in tufts; but these crystals, even when immersed in the solution, are quickly converted into rather broad, shining laminæ ($3H^2O$) having the form of quadrangular tables. The whole of the water is given off at 100°.

Hippurate of Magnesium, $C^{18}H^{16}Mg''N^2O^6 + 5H^2O$, forms white nodules, which are soluble in water and give off $2H^2O$ at 100°.

Hippurate of Nickel, $C^{18}H^{16}Ni''N^2O^6 + 5H^2O$, is crystallisable, insoluble in ether, sparingly soluble in cold water, more soluble in boiling water and in boiling alcohol. It becomes anhydrous at 100°.

Hippurate of Potassium.—The *neutral* salt, $C^9H^8KNO^3.H^2O$, forms oblique prisms with rhomboïdal base, soluble in water and in alcohol, and becoming anhydrous by

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desiccation at 100°. To obtain it pure, it must be crystallised several times from alcohol and washed with ether.

The *acid* salt, $C^9H^8KNO^3.C^9H^9NO^3.H^2O$, forms brilliant laminæ, which under the microscope are seen to consist of prisms with rectangular base, and the terminal edges truncated. They give off 4·77 per cent. water at 100°.

Hippurate of Silver, $2C^9H^8AgNO^3.H^2O$, prepared by adding nitrate of silver to hippurate of potassium, is soluble in water and crystallisable. It gives off its water (3·42 per cent.) at 100°.

Hippurate of Sodium, $2C^9H^8NaNO^3.H^2O$, is crystallisable, very soluble in hot water and in alcohol, sparingly in ether.

Hippurate of Strontium, $C^{18}H^{16}Sr''N^2O^6.5H^2O$, is crystallisable; sparingly soluble in cold water and alcohol; gives off its water at 100°.

Derivatives of Hippuric Acid.

Amido-hippuric acid. $C^9H^{10}N^2O^3 = C^9H^8(NH^2)NO^3$. (Schwanert, Ann. Ch. Pharm. cxii. 69.)—Obtained by passing sulphydric acid gas for a considerable time into a solution of nitrohippuric acid in saturated sulphide of ammonium, and acidulating the concentrated liquid with hydrochloric, or better with nitric acid. It crystallises in light white laminæ, soluble in 300 to 370 pts. water at 20°, in 1200 pts. absolute alcohol at 15°, insoluble in ether. In boiling water and alcohol it dissolves easily; likewise in acids and in alkalis; the solutions quickly turn brown. With concentrated hydrochloric acid, it forms a *hydrochlorate* containing $C^9H^{10}N^2O^3.HCl$.

Chlorohippuric acids. (R. Otto, Ann. Ch. Pharm. cxxii. 129.)—These compounds are produced by the action of hypochlorous acid on hippuric acid. When 2 or 3 pts. chlorate of potassium are added to a mixture of 1 pt. hippuric acid and 6 to 9 pts. hydrochloric acid, a gentle heat applied, after the frothing has ceased, to complete the reaction, the liquid then heated to boiling and left to cool,—an oily yellowish mass is deposited, consisting of mono- and dichlorohippuric acids, their relative quantities depending, partly on the quantity of chlorate used, partly on the temperature of the liquid during the reaction. The two acids are separated, either by boiling with water, which dissolves chiefly the monochlorinated acid, or by repeated crystallisation of the calcium-salts obtained by neutralising the mixed acids with milk of lime.

Monochlorohippuric acid, $C^9H^8ClNO^3$, obtained by evaporating the alcoholic solution, after decolorisation with animal charcoal, forms a yellowish, viscid, inodorous mass, having an acid reaction; it is nearly insoluble in cold water, melts and dissolves in boiling water, and mixes in all proportions with alcohol and ether. It dissolves also in caustic alkalis, forming a solution which turns brown when heated.—By boiling with concentrated hydrochloric acid, it is resolved into glycocine and monochlorobenzoic acid.

The *neutral potassium-* and *sodium-salts* are uncrystallisable or crystallise with difficulty. The *acid sodium-salt*, $2(C^9H^7ClNaNO^3.C^9H^8ClNO^3).H^2O$, crystallises in concentrically grouped needles.—The *calcium-salt*, $C^{18}H^{14}Cl^2Ca''N^2O^6.4H^2O$, crystallises from alcohol in small shining scales.—The *lead-salt*, $C^{18}H^{14}Cl^2Pb''N^2O^6$, melts at 100—120°, and crystallises from dilute alcohol in concentrically grouped needles.—The *silver-salt* is a white precipitate, which crystallises indistinctly from solution in water.

Dichlorohippuric acid, $C^9H^7Cl^2NO^3$, is very much like the monochlorinated acid, and after standing in contact with the air or under water, forms a soft granulo-crystalline mass, which deliquesces when warmed, and at 60° emits an aromatic turpentine-like odour.—By boiling with strong hydrochloric acid, it is resolved into glycocine and dichlorobenzoic acid.

Dichlorohippurate of sodium, $C^9H^6Cl^2NaNO^3.H^2O$, forms soft warty crystals, easily soluble in water, alcohol, and acids.—The *barium-salt*, $C^{18}H^{12}Cl^4Ba''N^2O^6.3H^2O$, crystallises in needles.—The *calcium-salt*; $C^{18}H^{12}Cl^4Ca''N^2O^6$, crystallises from dilute solutions at ordinary temperatures, or at 60°, in needles containing 9 or 10 at. water; at higher temperatures, in hard white crusts with 5 at. water.—The *neutral lead-salt*, $C^{18}H^{12}Cl^4Pb''N^2O^6.4H^2O$, obtained by cold precipitation, separates from its aqueous solution in nodules. A *basic lead-salt*, $2C^{18}H^{12}Cl^4Pb''N^2O^6.Pb''O.6H^2O$, may be extracted by boiling absolute alcohol from the precipitate formed by dichlorhippuric acid and acetate of lead at the boiling heat. The *silver-salt* is a white precipitate, which separates from hot water in cauliflower-like masses.

Dichlorohippurate of Ethyl, $C^9H^6Cl^2(C^2H^5)NO^3$, obtained by treating the alcoholic solution of the acid with hydrochloric acid gas, is a heavy yellowish oil, nearly insoluble in water.

A *calcium-salt* having the composition, $C^{18}H^{13}Ca''Cl^3N^2O^6.5H^2O$, intermediate between the mono- and dichlorohippurates, is obtained in spherical groups of needles by crystallising a mixture of the calcium-salts of the two acids. Its solution precipitated by nitrate of silver yields a *silver-salt* of analogous composition.

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of Pentachloride of Phosphorus on Hippuric acid.
xii. 59.)—When 1 at. hippuric acid (in quantities
with 2 at. pentachloride of phosphorus, scarcely
us passes over at first, but between 180° and 200°
en 220° and 250° a mass which solidifies in the
ted from the crystals gives off, on rectification,
then chloride of benzoyl, boiling at 196°, and an
e 200°, and when left over oil of vitriol, solidifies
ion is expressed by the formula, $C^9H^6ClNO^2$ =
) – H^2O, which is also the composition of the
ion.—This compound, when immersed in ether,
ellowish oil, without perceptibly dissolving, and
ed monoclinic prisms bevelled at the ends with
d 50°, distils without alteration at 200°, is in-
alcohol, and crystallises therefrom with difficulty.
oride of platinum, mercuric chloride, or nitrate of
posed by potash, either in aqueous or in alcoholic
th hydrate of potassium, it is partially resolved
us ammonia also decomposes it partially at 130°.
quantity corresponding nearly with the formula,
loses its acid, even when the alcoholic solution is

$H^3Cl^2NO^2$ = $C^9H^7Cl^2NO^3$ (dichlorohippuric acid)
mall quantity, by repeatedly rectifying the last
illing hippuric acid with pentachloride of phos-
dissolves readily in ether.

$C^9H^8(NO^2)NO^3$. (Bertagnini, Ann. Ch. Pharm.
y the action of a mixture of strong sulphuric and
It is found in the urine after nitrobenzoic acid
pt. of hippuric acid is dissolved, in the cold, in
the solution is mixed, slowly, so as to avoid rise
sulphuric acid. The liquid is then left to itself
, to avoid heating, with three times its volume of
its an abundant crystallisation of nitrohippuric
yellow colour; for purification, it is treated with
composed with hydrochloric acid, and the nitro-
times.
lourless silky needles, soluble in alcohol, ether,
ing phosphate of sodium. The crystals redden
nen decompose, giving off vapours of benzoic

puric acid into glycocine and nitrobenzoic acid.
with *ammonia* assumes a red colour under the
its sulphur when neutralised by an acid. When
phide of ammonium, and treated with sulphydric
puric acid, $C^9H^{10}N^2O^3$ (Schwanert, p. 160).
nitrohippuric acid in nitric acid gives rise to the
ined. Nitrohippuric acid dissolves at ordinary
and on gently heating the solution and then
is deposited. Nitrohippuric acid distilled with
reddish, oily distillate having the odour of cin-
solution of *potash*, turns brown and gives off
e mixture gives off hydrogen and assumes a red

soluble in water, some of them also in alcohol.
ouped round a common centre. When heated,
following have been analysed:

. . $C^{18}H^{14}Ca''(NO^2)^2N^2O^6.3H^2O$.
. . $C^{18}H^{14}Cu''(NO^2)^2N^2O^6.5H^2O$.
. . $C^{18}H^{14}Pb''(NO^2)^2N^2O^6$ (at 110°).
. . $C^9H^7Ag(NO^2)NO^3$.
. . $C^{18}H^{14}Zn''(NO^2)^2N^2O^6.6H^2O$.

SO^6 = $C^9H^9NO^3.SO^3$. (Schwanert, Ann. Ch.
t combination. Hippuric acid absorbs the vapour
n liquid; and by dissolving this product in water,
ecomposing the filtrate with sulphydric acid, and

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evaporating, sulphohippuric acid is obtained as a brownish yellow, amorphous, deliquescent mass.

With *nitrous acid* it forms (not sulphobenzoglycollic, but) sulphobenzoic acid, $C^7H^6SO^5$, together with an oily substance probably containing glycollic acid.

Sulphohippuric acid is dibasic. Its neutral *barium-salt* contains $C^9H^7Ba''NSO^6.H^2O$. By boiling the acid with hydrate of lead, a *lead-salt* is obtained corresponding approximately with the formula $C^9H^7Pb''NSO^6$.

HIPPURIC ETHERS. Only two of these compounds have as yet been obtained, viz. the ethylic and methylic ethers.

Hippurate of Ethyl. $C^{11}H^{13}NO^3 = C^9H^8(C^2H^5)NO^3$. (Stenhouse, Ann. Ch. Pharm. xxxi. 148.)—Prepared by passing hydrochloric acid gas through a boiling solution of hippuric acid in alcohol of 80 per cent. The liquid thickens, assumes an oily aspect, and when diluted with water, deposits the ether in liquid drops, which soon solidify.

Hippurate of ethyl is crystallisable and has a sharp taste. Specific gravity 1·043. Melts at 44° and solidifies at 32° C. Sparingly soluble in water, very soluble in alcohol. Chlorine, with the aid of heat, converts it into a crystallisable chlorinated compound. Nitric and sulphuric acids decompose it at the boiling heat, producing benzoic acid. Alcoholic potash converts it into ethylic alcohol and hippurate of potassium.

Hippurate of Methyl. $C^{10}H^{11}NO^3 = C^9H^8(CH^3)NO^3$. (Jacquemin and Schlagdenhauffen, Compt. rend. xlv. 1011.)—Prepared by passing hydrochloric acid gas into a soluton of the acid in wood-spirit heated to 50° or 60° C., washing the resulting syrupy liquid with carbonate of sodium, and then treating it with ether, from which the compound crystallises by spontaneous evaporation.

Hippurate of methyl forms white, transparent needles, soluble in 120 pts. of cold water, and in 60 pts. water at 30°; in boiling water it melts before dissolving. Alcohol and ether dissolve it in all proportions. It melts at 60° and decomposes at 250°, giving off ammonia and benzonitrile. With fuming nitric acid it gives off a combustible gas, probably containing nitrate of methyl. Alkalis decompose it, forming hippuric acid and methylic alcohols. Ammonia converts it into hippuramide.

HIRCIC ACID. The name given by Chevreul (*Recherches sur les corps gras*, pp. 151, 236) to an oily acid, slightly soluble in water, which he obtained from mutton-suet, and to which he attributes the peculiar taste and odour of that substance. The *potassium-salt* is very deliquescent; the *barium-salt* is sparingly soluble in water and contains 43·8 per cent. barium. The acid is probably nothing more than a mixture of several acids of the series $C^nH^{2n}O^2$.

HISINGERITE. A hydrated silicate of iron occurring at Ridharhyttan in Sweden and other localities. A variety called *Gillingite* is found in the Gillinge mine at Svärta-Kirchspiel in Sweden, and another called Thraulite at Bodenmais in Bavaria. These minerals all contain both protoxide and sesquioxide of iron, and are closely allied in composition; they are, however, but imperfectly crystallised, and have a dark colour, so that impurities in them easily escape detection. Moreover, it is possible that part of the protoxide of iron in the original mineral may be gradually converted into sesquioxide. Hence their constitution cannot be ascertained with certainty. The composition of hisingerite from Ridharhyttan (specific gravity 3·045) agrees however nearly with the formula $3(FeO.SiO^2).2(Fe^2O^3.3SiO^2) + 6H^2O$. Gillingite is the same with 9 at. water; Thraulite is $3(FeO.SiO^2).(Fe^2O^3.3SiO^2) + 6H^2O$. A variety from Orijärfvi in Finland, much richer in protoxide of iron, may be represented by the formula $9(FeO.SiO^2).(Fe^2O^3.3SiO^2) + 9H^2O$. The following are analyses of these minerals:

	SiO^2	Fe^2O^3	FeO	CaO	MgO	H^2O	
a.	33·07	34·78	17·59	2·56	0·46	11·54	= 100·0
b.	32·18	30·10	8·63	5·50	4·22	19·37	= 100·0
c.	31·28	49·12		. .	. .	19·12	= 99·52
d.	29·51	10·74	37·49	. .	7·78	13·00	= 98·52

a, from Ridharhyttan by Rammelsberg (*Mineralchemie*, p. 852).—*b*, from the Gillinge mine by Rammelsberg (*ibid.*).—*c*, Thraulite from Bodenmais by v. Kobell (Pogg. Ann. xiv. 467).—*d*, from Orijärfvi by Hermann. (J. pr. Chem. xlvi. 338.)

HISLOPITE. A grass-green limestone from Takli near Nágpur in Central India, of specific gravity 2·645, and containing 80·79 per cent. carbonate of calcium, 0·73 alumina, a trace of carbonate of magnesium, and 16·63 of an imbedded green silicate (= 98·15), perhaps identical with glauconite. (S. Haughton, Phil. Mag. [4] xvii. 16.)

HITCHCOCKITE. A silicate of lead and aluminium from the Canton mine in Georgia. Specific gravity, 4·024. Contains 20·85 per cent. P^2O^4, 27·40 PbO, 28·41

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Al^2O^3, 0·14 $PbCl^2$, and 23·20 water (= 100·00), agreeing nearly with the formula, $3PbO.P^2O^5.2[4Al^2O^3.P^2O^5.18H^2O] = Pb^3P^2O^8.2[(Al^2)^{vi}P^2O^8.3(Al^2)^{vi}H^6O^6] + 18H^2O$. (Genth, Sill. Am. J. [2] xxiii. 424.)

HJELMITE. A mineral consisting chiefly of tantalate of yttrium and iron, found in the neighbourhood of Ytterby, together with garnet, gadolinite, &c. in a rock consisting of quartz, orthoclase, albite, and mica. It has a metallic lustre, granular fracture, pure black colour in the mass, blackish grey in powder. Hardness = 5. Specific gravity = 5·82. It exhibits no distinct indications of crystalline form or cleavage. Its analysis gave:

Ta^2O^5	SnO^{2*}	CuO	CaO	YO	CeO	UO	FeO	MnO	MgO	H^2O
62·42	6·56	0·10	4·26	5·19	1·07	4·87	8·06	3·32	0·26	3·26 = 99·37

Before the blowpipe it decrepitates and flies to pieces, gives off water, and turns brown without melting, in the oxidising flame; by phosphorus-salt it is easily dissolved to a bluish-green glass; easily also by borax to a clear glass rendered opaque by flaming; by reduction on charcoal with carbonate of sodium, it yields metallic spangles. (Nordenskiold, Pogg. Ann. cxi. 273; Jahresber. 1860, p. 780.)

HOERNESITE. A hydrated arsenate of magnesium from the Bannat, found imbedded in calcspar. It forms rhomboïdal laminæ of 36° and 144°, bevelled on the sides, closely resembling the most common form of gypsum, and probably belonging to the monoclinic system, cleaving perfectly in the direction of the pinacoïdal face, having a mother-of-pearl lustre on the cleavage-faces; white, transparent (translucent in the thicker parts), flexible in thin layers. Hardness = 0·5. Specific gravity = 2·474. Splinters of it melt even in the flame of a candle. An analysis by v. Hauer (Rép. Chim. pure, ii. 286) gave 24·54 per cent. MgO, 46·33 As^2O^5, and 29·07 water (= 99·94), agreeing with the formula, $Mg^3As^2O^8.8H^2O$. (Haidinger, Wien. Akad. Ber. xi. 18.)

HOLCUS LANATUS. For the composition of the ash of this grass, see GRASSES (ii. 943).

HOLMESITE. See CLINTONITE (i. 1026).

HOMEOMORPHISM. See ISOMORPHISM.

HOMICHLIN. A mineral closely related to barnhardtite (i. 508), and copper pyrites (ii. 77), from Plauen in the Saxon Voigtland (and other localities), where it forms, together with carbonate and silicate of copper, a vein of copper-ore imbedded in greenstone. It occurs sometimes in quadratic crystals, but more generally massive. Hardness between 4 and 5. Specific gravity = 4·472 to 4·480. Colour, brass-yellow, but with more of a bronze tint than copper-pyrites, and quickly acquiring a many-coloured tarnish. Streak black. According to an analysis by Richter, it contains 25·81 per cent. iron, 43·76 copper, and 30·21 sulphur, agreeing with the formula, $3Cu^2S.Fe^2S^3.2FeS$. (Breithaupt, Sill. Am. J. [2] xxviii. 132; xxix. 373. *Rammelsberg's Mineralchemie*, pp. 426, 987.)

HOMOCUMINIC ACID. $C^{11}H^{14}O^2 = \left.\begin{matrix}C^{11}H^{13}O\\H\end{matrix}\right\}O$. *Cyminic acid.* (Rossi, Compt. rend. lii. 403; Ann. Ch. Pharm. Suppl. i. 139.)—An acid homologous with cuminic acid, prepared by treating cyanide of cymyl, $C^{10}H^{13}Cy$ (obtained by the action of cyanide of potassium on the chloride, ii. 296), with potash-ley at the boiling heat:

$$C^{10}H^{13}.CN + 2H^2O = C^{10}H^{14}O^2 + NH^3.$$

It crystallises in small needles; melts at 52°; distils without decomposition; dissolves sparingly in cold, easily in boiling water, also in alcohol and ether, reddens litmus and decomposes carbonates. The *potassium-salt* is deliquescent; the *barium-* and *calcium-salts* crystallise in needles; the *magnesium-salt* in nacreous scales; the *silver-salt* has the composition $C^{10}H^{13}AgO^2$.

The low melting point of this acid raises a doubt as to whether it is the true homologue of cuminic acid (which melts at 92°) or an isomer of that homologue related to it in the same manner as the acid $C^8H^8O^2$, obtained by Cannizzaro from cyanide of benzyl (probably α-toluylic acid), is related to the true toluylic acid.

HOMOLACTIC ACID. This name was given by Cloez (Compt. rend. xxxiv. 364) to an acid, isomeric if not identical, with glycollic acid, found in the mother-liquor which is obtained in the preparation of fulminating mercury. By neutralising this liquor with chalk, distilling off the volatile products (acetic ether, &c.), repeatedly crystallising the remaining solution by spontaneous evaporation, and decanting the liquid containing the more soluble salts, the calcium-salt of this acid was obtained in small light nodules resembling lactate of calcium.—The acid itself formed, when com

* With tungstic anhydride.

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centrated, a syrup which did not crystallise. The silver-salt crystallised in long thin laminæ, sparingly soluble in cold water.

HOMOLOGOUS SUBSTANCES. This term is applied to organic compounds differing from one another in composition by CH^2 or any multiple thereof; for example, the *alcohols* $C^nH^{2n+2}O$, the *fatty acids* $C^nH^{2n}O^2$, and the *aromatic acids* $C^nH^{2(n-4)}O^2$.—Bodies thus related exhibit, for the most part, a regular gradation of properties, both physical and chemical. Thus, in the series of fatty acids, formic acid, CH^2O^2, and acetic acid, $C^2H^4O^2$, are watery liquids without any trace of viscosity; propionic acid, $C^3H^6O^2$, is slightly oily; butyric acid, $C^4H^8O^2$, valeric acid, $C^5H^{10}O^2$, and a considerable number of others exhibit more and more of an oily or fatty character as their atomic weights increase; while palmitic acid, $C^{16}H^{32}O^2$, and stearic acid, $C^{18}H^{36}O^2$, and a few others, are at ordinary temperatures solid fats, exhibiting higher melting points as they rise higher in the series; and lastly cerotic acid, $C^{27}H^{54}O^2$, and melissic acid, $C^{30}H^{60}O^2$, are of the consistence of wax. Similar relations are observed in the series of alcohols, corresponding with these acids. Moreover, the chemical energy of bodies thus related continually decreases as their molecules become heavier. Common alcohol is violently decomposed by potassium and sodium, with rapid evolution of hydrogen; but on the fatty alcohols, these metals act but very slowly. Similar differences of character are observed between the higher and lower terms of the fatty acid series. Formic and acetic acids are highly corrosive liquids, which unite energetically with bases, and decompose carbonates with the greatest ease; whereas the solid fatty acids, stearic, palmitic acid, &c., exert no action on the animal tissues, do not enter readily into direct combination with any bases excepting the strongest, and decompose carbonates but slowly.

Bodies belonging to the same homologous series exhibit, for the most part, regular gradations of boiling point and of atomic volume. With regard to the latter, Kopp has shown that compounds whose chemical formulæ differ by n CH^2, differ in atomic volume by $n.22$ (i. 444). The relations of boiling point exhibited by homologous liquids are fully detailed in the article HEAT (p. 89).

Various attempts have been made of late years to build up the terms of homologous series, the higher from the lower. Frankland and Kolbe in 1847 (Ann. Ch. Pharm. lxv. 288) showed that a cyanide of an alcohol-radicle of the series C^nH^{2n+1}, may be converted into the next higher acid by boiling with aqueous potash, the action consisting in the assumption of the elements of water, with elimination of ammonia, *e.g.*:

$$\underset{\text{Cyanide of methyl.}}{CH^3.CN} + 2H^2O = \underset{\text{Acetic acid.}}{C^2H^4O^2} + NH^3;$$

and generally

$$C^nH^{2n+1}.CN + 2H^2O = C^{n+1}H^{2n+2}O^2 + NH^3.$$

Another method of passing from an alcohol to the next higher acid was discovered in 1859 by Wanklyn (Proc. Roy. Soc. x. 21), who showed that sodium-ethyl (prepared from zinc-ethyl, which is itself obtained from iodide of ethyl, and this from ethylic alcohol) exposed to the action of carbonic anhydride, absorbs that gas, and is converted into propionate of sodium:

$$C^2H^5Na + CO^2 = C^3H^5NaO^2.$$

Neither of these reactions, however, affords the means of obtaining one alcohol of the series from the next below it, because no method has yet been discovered of converting a fatty acid into the corresponding alcohol.

The great problem of passing from one alcohol to that next above it has, however, been solved in a general way by Mendius (Ann. Ch. Pharm. cxxi. 129), whose method consists in exposing the cyanides of the alcohol-radicles to the action of nascent hydrogen, thereby converting them into the amines of alcohol-radicles higher than the radicles started from. In this manner, starting from hydrocyanic acid, he obtains methylamine, thus:

$$\underset{\text{Cyanide of hydrogen.}}{HCN} + H^4 = \underset{\text{Methylamine.}}{CH^5N}$$

Methylamine treated with nitrous acid yields methylic alcohol (see AMINES, i. 174); this compound may be converted by well-known processes into cyanide of methyl; and this cyanide treated with nascent hydrogen yields ethylamine:

$$\underset{\text{Cyanide of methyl.}}{CH^3.CN} + H^4 = \underset{\text{Ethylamine.}}{C^2H^7N}.$$

From this last compound, by similar processes, we may ascend to the tritylic or propylic stage, and thus, by a repetition of the same reactions, the series of alcohols

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y step. The general equation representing the this series to the next highest amine is:

$$+ H^4 = C^{n+1}H^{2n+5}N.$$

y be found to succeed with cyanides derived from eries, and thus a general method of producing an xt below it may be obtained.

215), by heating ethyl-gas (C^4H^{10}) to 100° with g the composition and boiling point of dibromide

$$= C^4H^8Br^2 + 2HBr.$$

th dibromide of tetrylene, might be converted by ylene; and this by the action of hydriodic acid stillation with potash, tetrylic alcohol might be to give the means of mounting up the series by lemmer, by subjecting ethyl-amyl, $C^2H^5.C^5H^{11}$ $H^{15}.H$), to the action of chloride of iodine, has appears to be identical with chloride of heptyl dicle (p. 144). The problem of ascending from us series appears therefore to be capable of solu-

omology, and the relations between homologous rius (Ann. Ch. Pharm. cxxvi. 210).

mmon bee contains cane-sugar, inverted sugar cose. The proportion of cane-sugar varies with y converted into inverted sugar by the action of ording to Soubeiran (Compt. rend. xxviii. 774), ucose and a dextro-rotatory sugar capable of inver- tallisable sugar, possessing a lævo-rotatory power d sugar. The honey of the *Polybia apicipennis*, tropical America, yields cane-sugar in large crys- 0). The honey of the Mexican honey-ant is, em. Gaz. 1853, 72), a nearly pure solution of in vacuo); it has a slight acid reaction, and the xide of silver like formic acid.

fruit of the hop is formed of small membranous a yellow bitter powder called **lupulin** (*q. v.*), by Yves*, 36 per cent. resin, 12 wax, 11 of a ater and alcohol, 5 tannin, 10 extractive matter e insoluble in water. Yves found in hop-cones n. According to Payen and Chevallier, the pro- t., about 4 per cent. of which consists of minute lting from the sifting.

valerianic acid and a volatile oil, containing a lerol, $C^6H^{10}O$ (see Hops, Oil of). The resinous illation still retains a considerable portion of d lime, yields valeraldehyde, $C^5H^{10}O$.

s, according to Payen, Chevallier, and Pelletan, dissolved portion consists almost wholly of resin, latter soluble in water, whereas the resin, which lin, is insoluble. This resin, when purified by ion by water, and drying, gives by analysis num- formula, $C^{54}H^{70}O^{11}$, together with a quantity of according as the resin has been more frequently by water.

yen, Chevallier, and Pelletan, and called by them to between 8·3 and 12·5 per cent. of the lupulin. alic acid, in the water in which lupulin has been is saturated with chalk, the liquid evaporated to ether, which dissolves a small quantity of resin. he malate of calcium by solution in alcohol, and s prepared is white or yellowish, or sometimes nt, sometimes opaque. It has no odour, unless

*Payen, Chevallier, Pelletan, Wagner, Vlaanderen: *Résumé* (Rép. Chim. app. 1860, p. 21.)

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when strongly heated, in which case it exhales the odour of hops (perhaps in consequence of retaining a small portion of essential oil); it possesses the characteristic taste of hops. It has not been analysed. It is soluble in alcohol, but nearly insoluble in ether. By dry distillation it yields a considerable quantity of empyreumatic oil, but no ammoniacal products.

The tannin or astringent principle of the hop was for a long time regarded as identical with gallotannic acid, and as capable of conversion into gallic acid, and this change was supposed to account for the fact that old hops are not capable of clarifying beer. But, according to A. Wagner, gallic acid cannot be detected, even in very old hops quite unfit for making beer. He regards the tannic acid of hops as identical with morintannic acid, and finds that it amounts to between 3·2 and 5·7 per cent. of the hops.

According to Payen and Chevallier, the active principles of the hop do not reside exclusively in the lupulin, as was formerly supposed; they found, indeed, that hop-cones completely freed from lupulin, still yielded about 26 per cent. of substances soluble in alcohol.

To discover whether hops have been sulphured, Wagner treats them with granulated zinc, water, and pure hydrochloric acid. Any sulphurous acid that may be present is then reduced by the nascent hydrogen, and the liberated sulphur uniting with the hydrogen, forms sulphydric acid, which, if passed into a solution of nitroprussiate of sodium, generates a deep purple colour (ii. 257). This reaction will detect extremely small quantities of sulphurous acid; larger quantities may be detected by the odour, by the precipitation of iodine from a solution of iodate of potassium, and by various other reactions.

The ashes of hop-cones yield by analysis the following results:—

	Way and Ogston.*			H. Watts.†
	Bentley variety.	Golding variety.	Grape variety.	Grape variety.
Potash	11·98	24·88	25·56	19·41
Soda	. .	. .	. .	0·70
Lime	17·93	21·59	18·47	14·15
Magnesia	5·94	4·69	5·27	5·34
Alumina	. .	. .	. .	1·18
Ferric oxide	1·86	1·75	1·41	2·71
Sulphuric acid (SO^3)	7·01	7·27	11·68	8·28
Chlorine	. .	. .	. .	2·26
Silica	22·97	19·71	9 99	17·88
Carbonic acid (CO^2)	5·44	2·17	4·54	11·01
Phosphoric acid (P^2O^5)	21·38	14·47	17·58	14·64
Chloride of potassium	5·45	. .	4·34	
Chloride of sodium	. .	3·42	0·12	
Charcoal and loss	. .	. .	. .	2·44
	99·96	99·95	98·96	100·00
Ash per cent. of the dry substance	8·07	5·95	7·21	
,, ,, ,, fresh ,,	7·27	5·22	6·52	6·5

The hops analysed by Watts were grown on a heavy clay-soil near Hawkhurst in Kent. The crop was rather above the average, viz. 12 cwt. to the acre. By comparing this amount with the analysis of the ash, it is found that the hops grown on an acre of ground extracted from the soil 87 pounds of mineral constituents, including 12 to 13 oz. of phosphoric acid (P^2O^5), 17 lbs. potash (K^2O), and 15 lbs. 10 oz. of silica. This is sufficient to account for the well-known exhaustive effect of this plant on the soil. (For the statistics of the growth of hops in this country, see *Ure's Dictionary of Arts*, &c., ii. 460.)

HOPEITE. A cadmiferous zinc-ore from the calamine mines of Altenberg, near Aix-la-Chapelle. It has not been completely analysed, but appears to be a hydrated phosphate of zinc ... quantity of cadmium. It forms transparent or translucent pr... ...ric system, having a greyish-whi... and vitreo... ...reniform masses and ... gravity ... ...3 to 3. It is sectile. (D...

HO ...cones or lupulin distilled ...

...oyal Agricultural Society. ... xxxii. 54; Jahresber. ...

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having the odour of thyme, and consisting, according to R. Wagner (Dingl. pol. J. cxxviii. 217), of a hydrocarbon isomeric with oil of turpentine, and an oxygenated oil, apparently identical with valerol, $C^{8}H^{16}O$, and convertible by oxidation into valerianic acid, and perhaps also some of its higher homologues: hence the odour of old cheese, which hops acquire by keeping. The non-oxygenated oil is not altered by contact with the air, but the greater part of it is gradually dissipated by volatilisation.

According to Personne (J. Pharm. [3] xxvi. 2419; xxvii. 22), lupulin distilled with water, yields valerianic acid and an essential oil lighter than water, colourless and neutral after rectification, but becoming acid and resinous after some time. It begins to boil at 140° C., but the boiling point gradually rises to 300°. The portions distilling between 150° and 160°, and those which distil at about 300°, appear to have the same composition, viz. $C^{11}H^{18}O$. Both these portions of the distillate turn the plane of polarisation to the right; remain fluid at − 17°; dissolve without red colour in sulphuric acid; are converted by nitric acid into valerianic acid and a resinous substance; and when let fall by drops on melting caustic potash, yield a hydrocarbon, $C^{10}H^{16}$, and valerate of potassium. Hence, Personne regards the volatile oil of lupulin as analogous to essence of valerian, which, according to Gerhardt, consists of borneene, $C^{10}H^{16}$ (i. 626), and valerol, $C^{5}H^{10}O$. The hydrocarbon from oil of hops is not, however, identical with borneene, inasmuch as it cannot be converted into borneol.

HORDEIN. Barley-starch obtained by kneading barley-meal in water, and leaving the liquid to settle, does not dissolve completely when warmed with acidulated water, but leaves a pulverulent substance, to which Proust gave the name *hordein*. It appears, however, to be, not a definite substance, but a mixture of starch, cellular tissue, and an azotised body.

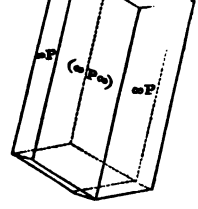
HORDEUM VULGARE. *Barley.*—The composition of the grain of barley, as determined by various observers, has been already given in the article Cereals (i. 825); also the composition of the ash of the grain, and of the straw and chaff, as determined by Way and Ogston, showing the limits between which the amounts of each constituent was found to vary. The following table (p. 168) contains a more detailed statement of the results of these ash-analyses.

HORN. See Horny Tissue (p. 170).

HORNBLENDE. *Amphibole.*—A mineral which plays an important part in the composition of rocks of the primitive and transition periods. Hornblende-rock and hornblende-slate consist almost entirely of it, and, in diorite (greenstone), syenite, hornblende-gneiss, &c., it enters as an essential constituent.

Hornblende forms prismatic crystals belonging to the monoclinic system. Ratio of axes, $a : b : c$, = 1·837 : 1 : 0·5401. Inclination of the clinodiagonal (b) to the principal axis (c) = 75·10°. The angle $\infty P : \infty P$ = 55° 30′; $+P : +P$ in the clinodiagonal principal section = 148° 30′; $oP : \infty P$ = 76° 59′. Ordinary combination $\infty P . [\infty P\infty] . +P . oP$. (*Fig. 556a.*) Twins with face of composition parallel to $\infty P\infty$, as in the figure. Cleavage perfect, parallel to ∞P. It is also found imperfectly crystallised; fibrous or columnar, coarse or fine, with fibres often like flax; sometimes lamellar, also granular, coarse or fine, and usually strongly coherent; sometimes friable. Hardness 5 to 6. Specific gravity 2·9 to 3·4. Lustre vitreous to pearly on cleavage-faces; fibrous varieties often silky. Colour varying from black to white, through various shades of green, inclining to blackish-green; common hornblende, which contains much iron, is nearly black. Streak uncoloured or paler than the mineral. Sometimes nearly transparent, usually translucent to opaque. Fracture subconchoïdal, uneven.

Fig. 556a.



The chemical composition of hornblende was formerly represented, in accordance with the results of older analyses, by the general formula $5M^{2}O.6SiO^{2}$ (or $4MO.3SiO^{2}$); but Rammelsberg (*Mineralchemie*, pp. 426, 494,) has shown, by comparison of the more recent analyses by himself and others, that all hornblendes are metasilicates, of the general formula $M^{2}O.SiO^{2}$ or $M^{2}SiO^{3}$. The metals included under the general symbol M are calcium, magnesium, iron and sodium, sometimes also manganese and potassium. These metals, replacing one another isomorphously, give rise to a great number of substances differing considerably in composition as well as in colour and other physical properties. A further variation is caused by the presence in many varieties of alumina, which enters, not in place of the protoxides $M^{2}O$, for the amount of the latter is not found to be in inverse proportion to that of the alumina, but in place of a certain portion of the silica, and in such proportion, according to Bonsdorff, that 1 at. SiO^{2} may be regarded as isomorphously replaced by 1 at. $Al^{2}O^{3}$ ($2SiO^{2}$ by $3Al^{2}O^{3}$), but according

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	Grain.									Straw (with chaff).				
	Chevalier barley					Barley from Moldavia			Long-eared Nottingham on sandy soil.	Moldavia barley raised on clay soil.	Chevalier barley.			Long-eared Nottingham raised on calcareous soil.
		raised on clay-soil.	raised on sandy soil.	raised on loamy soil.	raised on calcareous soil.		raised on clay soil.	raised on sandy soil.			raised on clay soil.	raised on loam soil.	raised on calcareous soil.	
Potash	26·83	22·43	24·97	28·60	37·22	19·78	26·61	22·46	32·02	12 69	11·22	14·37	20·18	16·18
Soda	. .	1·42	0·51	. .	. .	0·89	1·26	4·93	1·21	2·65	. .	0·28	3·29	. .
Lime	3·62	1·96	2·97	2·97	2·92	4·20	1·26	1·88	3·39	5·34	5·79	8·50	11·90	12·59
Magnesia	4·78	10·00	8·00	6·90	7·63	8·15	9·32	8·47	10·99	2·65	2·70	1·70	2·93	2·99
Ferric oxide	1·54	0·87	0·84	1·46	trace	0 93	0·24	0·10	0·15	0·10	1·72	0·20	0·31	0·32
Sulphuric acid (SO^3)	1·30	2·82	0·92	trace	0·26	0·39	0·47	0·53	trace	0·53	2·71	2·22	3·18	3·04
Silica	29·79	22·25	22·08	18·47	17·27	27·66	30·35	28·09	21·12	63·29	68·50	62·79	48·18	52·40
Carbonic anhydride (CO^2)	4·35	. .	. .	. .	. .	. .	. .	. .	0·48	. .	. .	1·25	3·55	3·89
Phosphoric anhydride (P^2O^5)	25·32	37·67	38·26	38·78	30·76	37·99	30·08	32·92	29·92	3·24	7·20	4·22	3·41	2·13
Chloride of potassium	. .	. .	. .	1·29	1·93	. .	. .	. .	. .	. .	. .	. .	. .	0 90
Chloride of sodium	2·47	0·56	1·44	1·59	2·01	trace	0·41	0·61	0·72	5·68	2·14	4·37	3·07	5·46
	100·00	99·98	99·99	100·00	100·00	99·99	100·00	99·99	100·00	99·97	100·00	100·00	100 00	100·00
Ash in 100 pts. of dried substance	2·32	2·65	2·47	2·28	2·39	2·28	2·55	2·07	2·20	6·80	. .	5·49	3·65	1·51
Ash in 100 pts. of fresh substance	2·03	2·30	2·15	2·07	2·13	2·03	2·31	1·79	1·99	6·12	. .	4·97	3·34	1·37
Moisture in 100 pts. of air-dried substance	12·50	13·20	13·20	9·20	11·16	11·24	13·00	10·00	9·20	10·00	. .	9·50	8·58	9·25
Sulphur in 1000 pts. of dry substance	3·53	0·96	1·21	0·74	1·83	2·42	1·54	1 58	1·41	1·56	. .	1·02	0·54	2·05

The results of these analyses show that, in barley as in other cereals, the amount of ash is but little influenced by the nature of the soil, but is for the most part greatest in plants grown on clay soils. The amount of ash in the straw and chaff varies between wider limits than that of the grain; the latter varies as much in plants growing on the same as in those growing on different soils. The composition of the ash of barley-grain does not differ essentially from that of wheat (*q. v.*) in any respect excepting in containing a larger amount of silica.

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$2Al^2O^3$ for $3SiO^2$ or Al^4 for Si^3, the quantity of mineral remaining unaltered.

se contain small quantities of fluorine, probably, m of a double fluoride of silicon and calcium, or mes present in small quantity.

ıtaining no iron fuse readily before the blowpipe, vhich is either transparent or exhibits various white opacity. With borax they form a colour- ruginous varieties fuse alone, with more or less l give with borax a transparent glass tinged with rd a deeper iron colour. Hornblende containing ke the non-ferruginous varieties; but the black l and give with borax a glass tinged with iron. a glass coloured by iron.

escriptions of the principal varieties of horn-

with little or no Alumina.

	CaO	FeO	MnO	Al^2O^3	Loss by ignition.		
5	13·95	. .	. .	. .	0·33		= 99·45
9	13·89	1·36	. .	0·38	0·40		= 99·12
2	15·06	2·41	. .	. .	3·33		= 99·43
9	13·42	3·88	. .	. .	2·36		=100·25
3	13·56	5·88	. .	0·97	2·20		=100·86
5	21·20	11·75	1·15	0·20	. .		=100·95
5	. .	13·94	2·38	. .	1·67		= 99·08
5	1·76	8·40	. .	4·03	. .		=100·24
9	3·55	2·10	. .	3·20	3·55		= 99 30
0	. .	32·60	. .	0·92	3·04	Na^2O 0·65	= 98·42
9	. .	8·10	. .	0·19	1·58		= 99·49
5	2·00	. .	46·74	. .	. .		=100·00
,	2·93	4·34	42·65	. .	. .		=101·13

. 273, 435; *Mineralchemie*, p. 468).—4. Scherer (Pogg. c. *cit.*).—6 Popping (Berz. Jahresber. xxvii. 252).—7. ckur (Rammelsberg's *Mineralchemie*, *loc. cit*).—9. th and Brush (Sill. Am. J. [2] xvi. 218).—11. Heintz pr. Chem. xlvii. 7).—13. Schlieper (Sill. Am. J. [2] ix.

, Si^4O^{12} = Ca″SiO^3.3Mg″SiO^3, is white, or with a

Crystals often in long slender blades, either or aggregated in columnar and radiated masses. or translucent. Found in the Tremola valley, in granular limestone or dolomite; in the Tyrol, c. *Calamite* is an asparagus-green variety of ne, at Normarken in Sweden.

).—This name includes hornblendes which are es containing chiefly magnesium, calcium, and Mg; Ca; Fe)″SiO^3. Actinolite occurs in bright rms; if in distinct rays, it is called *glassy actino-* risms, breaking easily in the transverse direction. and 3·05. Actinolite occurs at Greiner in the Helsingfors, and several other places in Finland; ylvania. *Raphilite* is an asbestiform actinolite

colour or some light shade, is usually a fibrous e darker specimens are varieties of anthophyllite. urs in masses of a fine columnar structure, or made yish brown colour, often with submetallic lustre. avage affords prisms of 124° 30′, like other varie- re found at Kongsberg in Norway, Kupferberg in l Cummington in Massachusetts.

his name vary considerably in composition; that

i^4O^{12}, or Fe″SiO^3.3Mg″SiO^3; that from Kupferberg

formula being Fe″SiO^3.6Mg″SiO^3. The minerals altered anthophyllites, the latter being approxi- Mg″SiO^3.3Fe″SiO^3.

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d. Cummingtonite is a rose-red granular hornblende from Cummington, Mass chusetts, of specific gravity 3·42, and consisting of manganous silicate, $Mn''SiO^3$.

e. Arfvedsonite.—This is a black mineral found in Greenland, accompanying eud lyte. It was formerly regarded as a variety of hornblende, with which indeed it isomorphous; but, according to Rammelsberg, it is a distinct species, whose formula $2(M^2O.SiO^2) + Fe^2O^3.3SiO^2$, or $\frac{M^4}{(Fe^2)^{vi}}\Big\}Si^2O^{15}$. Rammelsberg's analysis gives 51·22 p cent. SiO^2, 23·75 Fe^2O^3, 7·80 FeO, 1·12 MnO, 2·08 CaO, 0·90 MgO, 10·58 Na^2O, 0· K^2O, 0·16 water, and a trace of alumina.

II. *Hornblendes containing Alumina.*

	SiO^2	TiO^2	Al^2O^3	Fe^2O^3	FeO	MnO	MgO	CaO	Na^2O	K^2O	F	H^2O
1. Orange Co., N. Y., *limpid crystals*	51·67	. .	5·75	2·86	. .	. .	23·37	12·42	0·75	0·81	. .	0·46=
2. Brevig, Norway, *black* . .	42·27	1·01	6·31	6·62	21·72	1·13	3·62	9·68	3·14	2·65	. .	0·48=
3. Vesuvius . .	39·92	. .	14·10	6·00	11·03	0·30	10·72	12·62	0·55	3·37	. .	0·37=
4. Pargas, Finland, *light green* . .	46·12	. .	7·56	. .	2·27	. .	21·22	13·70	2·48	1·29	2·76	1·10=
5 Ural, *greenish black*	44·24	1·01	8·85	5·13	11·80	. .	13·46	10·82	2·08	0·24	0·25	0·39=
6 Val de Bove, Etna	40·91	. .	13·68	. .	17·48	. .	13·19	13·44	. .	. .	. .	0·85=

1—5. Rammelsberg (*Mineralchemie*, p. 490).—6. v. Waltershausen (*Vulkanische Gesteine*)

The minerals included under this head are mixtures of the isomorphous compound $M^2O.SiO^2$, $Fe^2O^3.3SiO^2$ and $3MO.2Al^2O^3$. (Rammelsberg.)

Common Hornblende.—This name is applied to the dark green and black alumino varieties, whether in crystals or massive. Specific gravity 3·1 to 3·4. The name allud to its toughness.—*Carinthin* is an aluminous and ferruginous hornblende from Cari thia. Specific gravity 3·127.

Uralite, from the Ural, has the cleavage structure and composition of hornblend but the external form of augite, and is regarded as a pseudomorph. The two speci are variously mingled in different specimens, showing the change in different stages progress.

Diastatite is a hornblende from Wermland in Sweden, differing, according to Brei haupt, from common hornblende, by a degree in the angle of the prism. *Pargasi* includes crystallised varieties (crystals usually thick and stout); of high lustre, ar rather dark shades of green. It is also granular.

Fine specimens of the dark-coloured hornblendes occur at Aussig and Treplitz Bohemia; Tunaberg in Sweden, and Pargas in Finland. In Corsica there is found variety of hornblende (*Verde di Corsica duro*) which admits of a high polish.

Altered forms of Hornblende.—Alterations of hornblende are mostly like those augite. Varieties often occur, containing water of hydration, especially asbestiform anthophyllite varieties. The ferruginous change by oxidation is common, and a varieties are exposed to alteration from infiltrating waters, holding carbonates, sil cates, &c., in solution, thus giving rise to magnesian, ferruginous, magnesio-ferruginou (chlorite), alkaline, or aluminous forms. Talc, steatite, serpentine, chlorite, mic pinite, chabasite, limonite, magnetite, occur as hornblende pseudomorphs.

HORNBLENDE-ROCK is a rock consisting either wholly of hornblende or that mineral mixed with quartz, and occasionally containing mica, iron pyrite magnetic iron ore, and garnet. *Hornblende-slate* is a slaty variety of hornblend rock. These rocks belong to the oldest formations; they seldom form extended bed occurring more generally in masses subordinate to granite, gneiss, &c.

HORN-LEAD. *Cerasine.* Native *chlorocarbonate of lead*, $PbCl^2.PbCO^3$, called from its external resemblance to horn.

HORN-QUICKSILVER. Native sub-chloride of mercury. (See Mercury.)

HORN-SILVER. Native chloride of silver. (See Silver.)

HORNSTONE. A variety of quartz resembling flint, but more brittle, and wit a more splintery fracture. It is often called *Chert*. It is often found as a petrifactio on wood, and is used for making mortars and various other articles.

HORNY TISSUE. *Epidermose.*—The epidermis of animals, hair, wool, sil feathers, nails, claws, hoofs, horn, scales, &c., are composed, for the most part, of substance containing less carbon, but more nitrogen and sulphur than the albuminoïd The epithelium which coats the internal cavities of the animal body, is also similarl constituted.

The substance, called horny tissue or epidermose, which forms the basis of all thes structures, is obtained, though very far from pure, by exhausting the parts containin it with boiling alcohol and ether, after they have been comminuted as much a possible. This treatment removes the fatty matters, together with the greater part

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the salts and other foreign matters, but it does not ensure the perfect homogeneity of the undissolved residue. It is known, indeed, that the horny tissues are composed of a number of superposed layers, cell-walls and nuclei, which are perhaps not all of the same nature, but yet cannot be separated by the solvents above mentioned.

The substance thus obtained from the various horny tissues, has been analysed by Mulder, Scherer, Frémy and several other chemists, the results of whose analyses, though not agreeing very closely, still show that the substance forming the basis of these several tissues has, in all probability, the same chemical composition.

	(1.) Scherer.*							
	Epidermis of Sole of Foot.	Hair of Beard.	Hair of Head.	Horn of Buffalo.	Nails.	Wool.	Quills.	Beard of Feathers.	Lining Membrane of Egg.
Carbon	51·0	50·0	49·9	51·3	50·4	50·0	51·7	51·8	50·0
Hydrogen	6·8	6·7	6·6	6·7	6·8	7·0	7·2	7·1	6·6
Nitrogen	17·2	17·9	17·9	17·2	16·9	17·7	17·9	17·6	16·8
Sulphur	. .	. .	. .	. .	. .	. .	. .	. .	. .
Oxygen	. .	. .	. .	. .	. .	. .	. .	. .	. .

	(2.) v. Laer.	(3.) Schlossberger.	(4.) Mulder.					(5.) Kemp.	(6.) Frémy.		
	Hair.	Horn of Ox.	White hairs of Cow.	Hoofs of Cow.	Hoofs of Horse.	Horn of Cow.	Nails.	Epithelium of Gall-bladder.	Hoofs of Reindeer.	Whale-bone.	Scale of Turtle.
Carbon	49·9	51·6	50·5	50·4	50·4	50·0	50·3	51·9	49·5	50·8	53·6
Hydrogen	6·4	6·8	6·8	6·8	7·0	6·8	6·9	8·0	6·2	7·4	7·3
Nitrogen	17·1	16·6	16·8	16·8	16·7	16·5	17·3	14·8	17·4	16·5	16·4
Sulphur	. .	5·0	5·4	3·4	3·0	3·4	3·2	. .	. .	. .	2·6
Oxygen	. .	20·0	20·5	23·4	22·9	23·3	22·3	. .	. .	. .	20·7
		100·0	100·0	100·0	100·0	100·0	100·0				100·0

The proportion of ash is about 1 per cent.

Horny tissue melts when heated, and burns with a bright flame, exhaling a peculiar odour.

When exposed to the action of boiling water in a Papin's digester, it gradually dissolves, yielding an extract, which does not gelatinise on cooling. By simple maceration in water, cold or warm, the horny tissues are gradually loosened, and exhibit a cellular structure more or less distinct.

Caustic potash easily dissolves horny tissue, eliminating ammonia, especially with aid of heat, and forming a yellow solution, which, when treated with acids, gives off sulphydric acid and yields a white precipitate. When fused with *hydrate of potassium* it gives off hydrogen, and forms acetic, butyric, and valerianic acids, also leucine, tyrosine, &c. Strong solutions of caustic potash or soda are the best reagents for bringing out the cellular structure of the different horny tissues, epidermis, nails, horn, &c.

Strong *sulphuric acid* causes horny tissue to swell up, and partly dissolves it when heated. The solution diluted with water becomes turbid when neutralised with an alkali, or mixed with ferrocyanide of potassium. Prolonged ebullition with dilute sulphuric acid yields tyrosine, leucine, ammonia, &c.

Nitric acid, especially if hot, colours horny tissue yellow, and ultimately dissolves it; on addition of ammonia, the yellow solution acquires a darker colour, and finally assumes an orange tint. According to v. Laer, xanthoproteic acid is formed in the first instance, then saccharic, and finally oxalic acid.

Fuming *hydrochloric acid* produces with horny tissue the same blue or violet coloration as with albuminous substances, and gradually dissolves the tissue on boiling. According to v. Laer, hair immersed even in cold concentrated hydrochloric acid dissolves in the course of some weeks.

Acetic acid does not dissolve horny tissue, but only causes it to swell up.

When *chlorine* is passed into water containing in suspension horny tissue (prepared from hair), the tissue undergoes no change in external appearance, but after drying it is harsh to the touch, and dissolves completely in ammonia, with evolution of nitrogen.

HORSE-CHESTNUT. *Aesculus Hippocastanum.*—The bark of this tree contains two fluorescent substances, æsculin (i. 60) and fraxin or paviin (ii. 708). Pelletier and Caventou found in it a greenish fat oil, a red-brown resin, a bitter yellow substance, a peculiar red substance, tannin, and woody fibre.

The fully developed leaves contain quercitrin, which is also found in the ripe

* (1.) Scherer, Ann. Ch. Pharm. xl. 55.—(2.) v. Laer, *ibid.* xlv. 156, 157.—(3.) Schlossberger (*Gerhardt's Traité*, iv. 197).—(4.) Mulder's *Chemische Untersuch*, No. 2, p. 270.—(5.) Kemp, Ann. Ch. Pharm. xliii. 115.—(6.) Frémy, Ann. Ch. Phys. [3] xlviii. 47.

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seeds, but not in the undeveloped leaves, or in the coatings of the buds, or in the bark of the stem and branches; the leaves which fall in autumn contain only traces of it. (Rochleder, Wien. Akad. Ber. xxxi. 565.)

The seeds contain, according to Tipp (Vierteljahrschr. pr. Pharm. iii. 19), starch (about 14 per cent.), mucilage, gum, a non-drying oil, saponin, a tannic acid which turns iron-salts green, phosphoric acid, and calcium-salts. Frémy found in the seeds, saponin, a yellow colouring matter [? quercitrin] and a crystallisable bitter substance. Attempts have been made at various times to render the starch of horse-chestnut seeds fit for food by freeing it from the bitter substance by means of a weak alkaline ley. According to Flandin (Compt. rend. xxvii. 391) this is best effected by kneading the peeled and bruised seeds with water containing from $\frac{1}{100}$ to $\frac{1}{50}$ of their weight of carbonate of soda, and then washing them; perfectly white starch then separates, which may be used as an addition to wheat-flour. According to Belloc, the same result may be obtained by the use of pure water. But according to Flandin, the alkali is required to remove an acrid substance and an acid resin, as well as the bitter principle. (Compt. rend. xxviii. 83, 138.)

The cotyledons of horse-chestnut seeds have lately been examined by Rochleder (Wien. Akad. Ber. xlv.; Rép. Chim. pure, 1863, p. 219), who finds, in the alcoholic extract, a bitter substance, argyrescin, an amorphous yellow colouring matter, and a substance which he calls aphrodescin, formerly regarded by Frémy as saponin. These substances are extracted by successive treatment with alcohol, acetate of lead, water, and ether.

Argyrescin, $C^{54}H^{86}O^{24}$, is soluble in water and in alcohol, and is precipitated by ether from its solution in absolute alcohol. When the aqueous solution is evaporated, it remains in the form of a gummy mass. From its solution in weak alcohol, it separates on evaporation in microscopic crystals, having a silvery lustre. The crystals have the composition $2C^{54}H^{86}O^{24}.H^2O$. It dissolves in strong sulphuric acid, forming a solution which turns red when mixed with water. It is fusible, and burns with a very smoky flame.

Argyrescin is resolved by *acids* into argyrescetin and glucose:

$$C^{54}H^{86}O^{24} = C^{42}H^{62}O^{12} + 2C^6H^{12}O^6;$$

and by *alkalis* into æscinic acid, $C^{46}H^{80}O^{22}$, and propionic acid:

$$C^{54}H^{86}O^{24} + 3H^2O = C^{46}H^{80}O^{22} + 2C^3H^6O^2.$$

With alkalis, however, an intermediate product is sometimes obtained, namely, an acid whose barium-salt has the composition $C^{51}H^{82}Ba^2O^{24}$, thus:

$$C^{54}H^{86}O^{24} + 2H^2O = C^{51}H^{84}O^{24} + C^3H^6O^2.$$

This new acid likewise exists, ready-formed, in the cotyledons.

Aphrodescin, $C^{42}H^{64}O^{22}$, is soluble in water, and is precipitated from the hot solution by hydrochloric acid in bulky flocks. It is distinguished from saponin by its solubility in alcohol, and by its reaction with alkalis, which is similar to that of argyrescin, excepting that it yields butyric instead of propionic acid, thus:

$$C^{42}H^{64}O^{22} + 2H^2O = C^{40}H^{60}O^{22} + C^4H^8O^2.$$

Æscinic acid, $C^{46}H^{80}O^{22}$, is obtained by precipitation from its salts, as a gelatinous mass, becoming pulverulent when dry. When boiled with a quantity of alcohol not sufficient to dissolve it completely, it becomes partly crystalline, but does not alter in composition. By drying at 130° in a current of carbonic anhydride, it undergoes a decomposition, which Rochleder represents by the improbable equation $C^{184}H^{320}O^{98} = C^{92}H^{160}O^{46}$ (æscinic acid) + $C^{92}H^{160}O^{52}$.

Æscinate of potassium, $C^{46}H^{79}KO^{22}$, is crystallisable.—The *barium*-salt has the composition $C^{46}H^{78}Ba^2O^{22}$.—The *lead*-salt contains a still larger proportion of base.

Argyrescin, aphrodescin, and æscinic acid heated with hydrochloric acid, are resolved into sugar and a new substance, telescin $C^{26}H^{42}O^{14}$, or a product containing $C^{42}H^{70}O^{16}$. When these decompositions take place in alcoholic solutions, the products formed are not constant, because the telescin may then be further resolved into mannitan (?) and a compound isomeric with quinovic acid.

Æscinic acid, or rather telescin, dissolved in alcohol, mixed with hydrochloric acid, and boiled till a red colour is produced, undergoes a final decomposition, yielding a solution from which water throws down flocks of æscigenin, $C^{24}H^{38}O^4$, isomeric with choloïdic and with quinovic acid. This substance is soluble in sulphuric acid, and on adding sugar to the solution, a red colour is produced similar to that exhibited by the biliary acids when similarly treated.

The action of hydrochloric acid on an alcoholic solution of telescin or æscinic acid sometimes also yields an intermediate product $C^{26}H^{42}O^5$, which is isomeric with

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Silica	0·70	1·97	0·87	4·27	0·60	1·31	0·58	1·13	0·64	0·16	0·43	0·15	0·37	0·69
Carbonic acid (CO^2) .	37·92	24·16	16·78	12·89	17·64	22·17	21·47	21·58	15·75	17·83	24·61	13·07	27·97	18·88
Phosphoric acid (P^2O^5) .	3·75	14·58	12·32	19·48	14·07	12·94	15·33	13·31	17·55	18·74	3·98	19·15	5·40	15·36
Chloride of potassium .	3·64	9·67	21·40	9·24	8·91	3·88	4·58	6·20	8·46	3·48	15·42	19·38	2·20	9·02
	100·00	100·00	100·00	100·00	100·00	100·00	102·90	100·00	100·00	100·00	100·18	100·00	100·00	100·00
Ash per cent. . .	7·85	1·05	13·38	7·62	11·36	6·65	6·56	6·10	4·39	3·36	7·29	2·26	4·53	1·70
Moisture . . .	54·98	48·45	84·04	75·41	85·21	83·16	83·60	86·67	81·01	52·88	82·70	49·67	81·12	64·00
Percentage of ash soluble in water . . .	11·35	29·21	59·38	39·77	81·16	72·70	72·22	72·70	77·77	77·02	85·37	. .	81·96	31·23

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quinovin, and may be regarded as a compound of æscigenin with 2 at. propionic acid:

$$C^{36}H^{56}O^{8} = C^{32}H^{50}O^{4} + 2C^{3}H^{4}O^{2}.$$

This view of its composition is supported by the formation of a compound, $C^{38}H^{44}O^{7}$ [?$C^{38}H^{46}O^{8}$], containing the elements of æscigenin and acetic acid, by the action of chloride of acetyl on æscigenin.

Rochleder considers it probable that æscigenin or its compounds may exist in other plants, and that cyclameïn and digitaliretin may belong to this group of compounds.

The ash of the different parts of the horse-chestnut tree has been analysed by E. Wolff (J. pr. Chem. xliv. 385; Jahresber. 1847–8, p. 1078), for the purpose of determining how the proportion of the different mineral constituents are modified in passing from one organ to another, and how these constituents are distributed throughout the several organs. To eliminate any local character from the results, the organs subjected to examination were selected from trees growing on two very different soils; one a stony porphyritic soil, the other a moist forest soil often overflowed, very rich in vegetable mould, and much more favourable to the growth of the trees than the former.

The mineral constituents were extracted by first charring the substance in a muffle heated not quite to redness, and exhausting the charcoal, first with water, then with dilute hydrochloric acid, drying the carbonaceous residue, and incinerating it completely in the muffle. The ash was then likewise exhausted with hydrochloric acid, and the united hydrochloric extracts, the aqueous extract, and the insoluble residue, were separately analysed. The results are given in the table on page 173.

The ash of the wood, bark and leaves of the horse-chestnut has also been analysed by E. Staffel (Ann. Ch. Pharm. lxxvi. 379; Jahresber. 1850, p. 661), chiefly with the view of determining whether the amount of the several inorganic constituents in the plant and its different organs varies with the season of the year. The method of analysis was similar to that adopted by Wolff, excepting that the charcoal was exhausted with water alone.

Ash of Horse-chestnut (Staffel).

	Wood.		Bark.		Leaves.	
	Spring.	Autumn.	Spring.	Autumn.	Spring.	Autumn.
Potash . . .	57·57	17·54	54·96	22·61	46·38	18·17
Lime . . .	5·92	50·99	9·24	61·34	13·17	40·48
Magnesia . . .	4·08	5·17	4·36	3·99	5·15	7·78
Alumina . . .	. .	0·23	. .	0·18	0·41	0·51
Ferric oxide* . .	0·31	0·63	1·66	0·31	1·63	4·69
Sulphuric acid (SO^3) .	0·82	. .	. .	1·05	2·45	1·69
Silica . . .	1·80	0·71	0·67	1·06	1·76	13·91
Phosphoric acid (P^2O^5)	19·02	21·73	19·54	6·95	24·40	8·22
Chloride of potassium	10·47	2·98	9·56	2·50	4·65	8·55
	99·99	99·98	99·99	99·99	100·00	100·00
Ash per cent. of dry substance . .	10·908	3·88	8·68	6·57	7·69	7·52
Ash per cent. of fresh substance . .	1·198	1·693	1·342	3·171	1·376	3·288
Moisture in 100 parts of air-dried substance . . .	89·01	49·90	84·45	51·73	82·09	56·27

HORSE-FLESH ORE. A term applied by the Cornish miners to certain varieties of *purple copper*.

HOUGHITE. A hydrated aluminate of magnesium, occurring, as the material of pseudomorphous spinel, near Oxbow, and in Rossie, near Somerville, St. Lawrence county, New York. The crystals are in all conditions, from the pure spinel to octahedrons with rounded edges and pitted or irregular surfaces; it also occurs in flattened nodules. It is perhaps identical with *Völknerite* (*q. v.*). (Dana, ii. 135.)

HOVITE. A mixture of collyrite (i. 1084) with a hydrated carbonate of aluminium and calcium, found in the Upper chalk, in the neighbourhood of Hove, near Brighton. It is very soft and friable, having an earthy fracture and low specific gravity. (J. H. and G. Gladstone, Phil. Mag. [4] xxiii. 461; Jahresber. 1862, p. 743.)

* With a trace of manganic oxide.

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HOWARDITE. A meteoric mineral, described by C. U. Shepard. (Sill. Am. J. [2] vi. 402.)

HUANOKINE. $C^{20}H^{24}N^2O$.—An alkaloïd, isomeric, or perhaps identical, with cinchonine; obtained from *China de Huanoco plana*, a cinchona-bark found in the Huanoco forests, north of Lima (A. Erdmann, Ann. Ch. Pharm. c. 341). The bark is repeatedly exhausted with water containing hydrochloric acid, and the base, precipitated by caustic soda, is purified by repeated solution in acid, and reprecipitation, till it becomes white, and finally by crystallisation from alcohol.

Huanokine crystallises in small colourless prisms, very similar in form to cinchonine. According to H. Hahn (Jahresber. 1858, p. 372), they are monoclinic prisms, exhibiting the faces ∞P . $\infty P\infty$. oP. Angle $\infty P : \infty P$ in the clinodiagonal principal section = 71°; $oP : \infty P\infty$ = 110°. Cleavable parallel to oP; less distinctly parallel to $\infty P\infty$. It is tasteless; but has a slight alkaline reaction, stronger in the alcoholic solution, which is also slightly bitter. It melts without decomposition, and solidifies in the crystalline form on cooling: at a stronger heat it sublimes. It is nearly insoluble in water, dissolves in 400 pts. alcohol of 80 per cent. at 17°; and in 110 pts. at the boiling heat; in 600 pts. ether at 17°; and in 470 pts. at the boiling heat. It is said to be a strong febrifuge.

The salts of huanokine are precipitated white by alkalis and alkaline carbonates, yellowish white by tincture of galls, white by mercuric chloride, yellow by chloride of gold.

The *sulphate* is nearly insoluble in water; but dissolves easily in excess of acid; the solution is not fluorescent.—The *hydrochlorate* is very soluble, and crystallises in large colourless prisms having an extremely bitter taste; not fluorescent. According to Hahn (*loc. cit.*) the crystals are rhombic prisms, with the faces $\infty P\infty$. $\breve{P}\infty$. P. Angle $\infty P : \infty P$ = 80°.— The *chloroplatinate* also forms rhombic crystals, ∞P . $\infty \breve{P}\infty$. P. Angle $\infty P : \infty P$ = 75°; angle between the macrodiagonal terminal edges and the principal axis = 132°.— The *tartrate* forms hemihedral rhombic crystals, ∞P . $\infty \breve{P}n$. oP . $\frac{P}{2}$. Angle $\infty P : \infty P$. = 138°; $\frac{P}{2} : \frac{P}{2}$ = 70°. (Hahn.)

According to De Vry (J. Pharm. [3] xxxii. 328), huanokine is identical with cinchonine, the differences observed by Erdmann between it and cinchonine having been probably due to admixture of quinidine or cinchonidine. He found that hydriodate of cinchonine agreed perfectly, in external character and in its relations to polarised light, with the hydriodate obtained from huanokine prepared by Erdmann himself.

HUDSONITE. A black mineral from Cornwall, Orange County, New York, near the Hudson River. Specific gravity 3·43 to 3·5. It cleaves like Hedenbergite, and is regarded by Dana as a variety of augite, having a considerable portion of the silica replaced by alumina. The composition is, however, more like that of hornblende. Smith and Brush (Sill Am. J. [2] xvi. 369) found in it:—

SiO^2	Al^2O^3	FeO	MnO	CaO	MgO	K^2O	Na^2O	Loss by ignition.
38·94	10·41	30·48	0·60	10·36	3·00	2·48	1·66	1·95 = 99·88

Kenngott found that a mineral from Monroe, designated as Hudsonite, was really a hornblende. (*Rammelsberg's Mineralchemie*, p. 996.)

HUMBOLDTILITE. Syn. with Melilite.

HUMBOLDTINE. Syn. with Oxalite.

HUMBOLDTITE. Syn. with Datholite.

HUMIC ACID. See Ulmic acid.

HUMITE. See Chondrodite (i. 930).

HUMOPIC ACID. $C^{22}H^{25}O^7$ (?) (Wöhler, Ann. Ch. Pharm. l. 21).—An acid produced, with evolution of ammonia, by heating narcotine to about 220°.

$$C^{22}H^{23}NO^7 = C^{22}H^{25}O^7 + NH^3 [?]$$

It is purified by dissolving it in potash, precipitating with hydrochloric acid, re-dissolving in alcohol, and precipitating by water. It is an amorphous, dark-brown substance, insoluble in water and in dilute acids, but dissolves in alcohol with yellowish-red, and in alkalis with yellow colour, the latter solution forming brown gelatinous precipitates with barium- and lead-salts.

Wöhler's analysis of this acid gave 63·0 and 64·5 per cent. carbon, 5·3 and 5·0 hydrogen; whence he suggested the formulæ, $C^{44}H^{22}O^{27}$ and $C^{40}H^{19}O^{14}$. The formula above given (which requires 66·7 per cent. carbon and 5·3 hydrogen) is based upon the formula of narcotine recently established by Matthiessen and Foster (*Gmelin's Handbook*, v. 138). It is probable, however, that the acid has not been obtained pure,

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and that the decomposition of narcotine by heat may be more complicated than that which is represented by the preceding equation.

HUMOURS OF THE EYE. See Eye (ii. 654).

HUMUS, or *Vegetable Mould*, is the product of the decay of vegetable matter. The fallen leaves, and all the parts of plants which are returned to the soil, either during the life of the plant or after its death, undergo peculiar alterations, the result of which is to transform them into a mass of compounds whose nature has not been exactly ascertained, but which are known to contain a large proportion of carbon. This decay is promoted by the action of air, by moisture, and by a certain degree of heat. It takes place most quickly in those constituents of the plant which are soluble in water, some of the insoluble matters, such as resins and fats, resisting decomposition for a long time, and remaining almost in their original state, so that they may be extracted from the humus by alcohol or ether. The decomposition is also greatly accelerated by the presence of putrifying nitrogenous matters; and this is doubtless one cause of the beneficial effect of animal manure.

Vegetable mould is in a continual state of slow combustion, whereby the organic compounds which it contains are gradually resolved into carbonic acid, water, and ammonia, which, as they are formed, are taken up by the roots and plants: hence the effect of vegetable mould in promoting the growth of plants, and partly also the advantage gained by frequently turning up and pulverising the soil, whereby the access of air and the decomposition of the organic matter are facilitated.

HUNTERITE. The name applied by S. Haughton (Phil. Mag. [4] xvii. 18; Jahresber. 1859. p. 289) to a hydrated silicate of aluminium, having a fatty lustre and the aspect of felspar, found in a coarsely crystalline granite in the neighbourhood of Nágpur in Central India. Specific gravity = 2·319. According to Haughton's analysis, it contains 65·93 per cent. SiO^2, 20·97 Al^2O^3, 0·30 CaO, 0·45 MgO and 11·61 water (= 99·26). This is very nearly the composition of cimolite (i. 984), with which also the mineral agrees nearly in lustre and specific gravity: hence Dana (Sill. Am. J. [2] xxviii. 133) regards it as identical with cimolite.

HUREAULITE. A phosphate of iron and manganese from Hureault, near Limoges, where it occurs in small veins in the granite. It forms translucent crystals belonging to the monoclinic system, having a yellowish- or reddish-brown colour and vitreous lustre. Specific gravity = 2·27. Somewhat softer than felspar; contains, according to the mean of Damour's analyses (Ann. Min. [5] v.), 38·00 per cent. P^2O^5, 41·67 MnO, 7·86 FeO, 11·98 water, and 0·38 quartz &c.; whence the formula $\left.\begin{matrix}\frac{5}{6}MnO\\ \frac{1}{6}FeO\end{matrix}\right\}^3.2P^2O^5 + 5H^2O$; or it may be a double salt consisting of a pyro- and ortho-phosphate, of the form $M^4P^2O^7.2M^3PO^4.5H^2O$. (*Rammelsberg's Mineralchemie*, p. 330.)

HURIN. An acrid crystalline substance obtained from the juice of *Hura crepitans*. (Boussingault and Rivero, Ann. Ch. Phys. [2] xxviii. 430.)

HURONITE. A mineral from Lake Huron, containing 45·80 SiO^2, 33·92 Al^2O^3, 8·04 CaO, 4·32 FeO, 1·72 MgO and 4·16 water. It forms imperfectly laminated masses, having a light greenish yellow colour and waxy lustre, translucent on the edges. (Handw. d. Chem. iii. 942.)

HVERSALT. Native iron-alum from Iceland. (See Sulphates.)

HYACINTH. See Zircon.

HYÆNANCHE GLOBOSA. (Lamb).—A euphorbiaceous plant, the pericarp of which contains a very acrid poisonous substance, resembling strychnine and the allied poisons in its action. The poisonous substance is uncrystallisable, easily soluble in water and in alcohol; it has neither basic nor acid properties, but cannot be classed among the resins, on account of its solubility in water. The husk of the fruit contains 9·40 per cent. water, 5·36 gypsum, lime, potash, and chlorine; 2·52 wax and chlorophyll; 9·64 tannic acid; 5·64 resin; 15·15 starch, gum, and sugar; 3·99 varnish-like substance, soluble in water and in alcohol; 36·00 cellulose; and lastly, oxalic acid, and substances which can be extracted by strong hydrochloric acid and potash-ley. The seeds give up to ether, 41·06 per cent. of a green-yellow fat oil, then to alcohol 24·13 per cent. of a nearly black, brittle resin, resembling kino; they contain 10·7 per cent. of inorganic matters. (J. B. Henkel, Arch. Pharm. [2] xciv. 16; Jahresber. 1858, p. 532.)

HYALITE. See Opal.

HYALOMELANE. Syn. with Trachylyte.

HYALOPHANE. A barytic felspar resembling adularia, discovered by Sartorius v. Waltershausen (Pogg. Ann. xciv. 134; c. 547) in the dolomite of the Binnenthal in the Valais. It is transparent and colourless when pure, but often milk-white from admixture of sulphate of barium. Hardness between 6 and 7. Specific

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gravity = 2·77 to 2·83. It forms monoclinic crystals resembling those of adularia, ∞P . oP . $+P\infty$, often with ($\infty P\infty$). Angle ∞P: ($\infty P\infty$) = 120° 36′; oP : ∞P = 112° 0′; oP : $+P\infty$ = 130° 36′. Cleavage perfect parallel to $P\infty$ (Waltershausen). The analysis of a perfect limpid specimen by Stockar-Escher (*Kenngott's Uebersicht*, 1856–57, p. 107) gave:

SiO^2	Al^2O^3	BaO	CaO	MgO	K^2O	Na^2O	H^2O
52·67	21·12	15·05	0·46	0·04	7·82	2·14	0·58 = 99·88;

whence the formula $\left.\begin{matrix}BaO\\K^2O\end{matrix}\right\}SiO^2 + Al^2O^3.3SiO^2 = \left.\begin{matrix}Ba^{\cdot}K^{\cdot}\\Al'''\end{matrix}\right\}Si^2O^6 = \left.\begin{matrix}\overset{\cdot\cdot}{Si^2}\\(Ba^{\cdot}K^{\cdot})'\\Al'''\end{matrix}\right\}O^8$;

which is similar to that of andesin (see FELSPAR, ii. 618). (*Rammelsberg's Mineralchemie*, p. 609.)

HYALOSIDERITE. A variety of chrysolite from the Kaiserstuhl mountain in the Breisgau, where it occurs in yellowish and brownish-red crystals. It contains 31·63 SiO^2, 32·40 MgO, 28·49 FeO, 0·48 Fe^2O^3, 2·21 Al^2O^3, 2·79 K^2O, and a trace of chromium. To bring it under the formula of chrysolite, $2M^2O.SiO^2$ or M^4SiO^4, it is necessary to suppose that part of the silica is isomorphously replaced by alumina.

HYELITE. See PALAGONITE.

HYDANTOIC ACID. $C^4H^8N^4O^4$ (?)—An acid produced by the action of potash on allantoïn. On supersaturating the solution with acetic acid, precipitating with acetate of lead, decomposing the lead-salt with sulphuretted hydrogen, and evaporating the filtered liquid, the acid is obtained as an uncrystallisable syrup, deliquescent and insoluble in alcohol. It probably contains the elements of allantoïn *plus* 1 at. water ($C^4H^6N^4O^3.H^2O$). (Schlieper.)

The name hydantoic acid is also applied by Baeyer to an acid formed from hydantoïn by addition of the elements of water: no description of it has yet been given.

HYDANTOÏN. $C^3H^4N^2O^2$. (A. Baeyer, Ann. Ch. Pharm. cxvii. 179.)—A compound belonging to the parabanic acid group, produced from allantoïn by the reducing action of hydriodic acid:

$$\underset{\text{Allantoïn.}}{C^4H^6N^4O^3} + 2HI = \underset{\text{Urea.}}{CH^4N^2O} + \underset{\text{Hydantoïn.}}{C^3H^4N^2O^2} + I^2.$$

Also, together with a small quantity of allanturic acid, by the action of hydriodic acid on alloxanic acid:

$$\underset{\text{Alloxanic acid.}}{C^4H^4N^2O^5} + 2HI = \underset{\text{Hydantoïn.}}{C^3H^4N^2O^2} + CO^2 + H^2O + I^2.$$

It crystallises with great facility in colourless crystals easily soluble in water; tastes slightly sweet, and grates a little between the teeth. It is converted by oxidation into allanturic acid:

$$\underset{\text{Hydantoïn.}}{C^3H^4N^2O^2} + O = \underset{\text{Allanturic acid.}}{C^3H^4N^2O^3}.$$

With water it forms Baeyer's hydantoïc acid.

HYDRACIDS. A term formerly applied to hydrochloric, hydrobromic, hydriodic, hydrofluoric, and hydrocyanic acids, to distinguish them from acids containing oxygen. The distinction is, however, no longer maintained, all acids being now regarded as salts of hydrogen. (See ACIDS.)

HYDRACRYLIC ACID. $C^{12}H^{22}O^{11}$.—An acid produced by the decomposition of iodopropionic acid, when a solution of a salt of that acid is heated to boiling:

$$4C^3H^5IO^2 + 3H^2O = C^{12}H^{22}O^{11} + 4HI.$$

It is most easily prepared by digesting iodopropionic acid with excess of silver-oxide, decomposing the resulting silver-salt with sulphydric acid, and evaporating the filtrate. Hydracrylic acid then remains in the form of a syrup, mixed with slender needles. It is tribasic; nearly all its salts are easily soluble in water, and many of them are decomposed by heat, with formation of acrylic acid:

$$\underset{\text{Hydracrylic acid.}}{C^{12}H^{22}O^{11}} = 4\underset{\text{Acrylic acid.}}{C^3H^4O^2} + 3H^2O.$$

The *cupric salt* is a blue-green varnish. The *lead-salt*, $C^{24}H^{20}(Pb'')^2O^{22}$, forms a white, crystalline, deliquescent mass, perfectly insoluble in alcohol, and decomposing when heated to between 150° and 200°. The *silver-salt*, $C^{12}H^{18}Ag^4O^{11}$, is a flocculent mass, becoming dark-coloured and amorphous when dry, easily soluble in water, sparingly in alcohol, insoluble in ether; decomposing below 100°. (Beilstein, Ann. Ch. Pharm. cxxii. 366.)

HYDRAMIDES. A group of tertiary diamides (i. 172), formed by the action

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of ammonia on certain aldehydes, 2 at. of ammonia uniting with 3 at. of the aldehyde, and 3 at. water being eliminated, as shown by the equation—

$$\underset{\text{Bitter Almond Oil.}}{3C^7H^6O} + 2NH^3 = \underset{\text{Hydrobenzamide.}}{N^2(C^7H^6)^3} + 3H^2O$$

The following are the hydramides at present known:—

Furfuramide . . .	$C^{15}H^{12}N^2O^3$	$= N^2(C^5\ddot{H}^4O)^3$
Hydranisamide . . .	$C^{24}H^{24}N^2O^3$	$= N^2(C^9\ddot{H}^8O)^3$
Hydrobenzamide . . .	$C^{21}H^{18}N^2$	$= N^2(C^7\ddot{H}^6)^3$
Hydrocinnamide . . .	$C^{27}H^{24}N^2$	$= N^2(C^9\ddot{H}^8)^3$
Hydrosalicylamide . . .	$C^{21}H^{18}N^2O^3$	$= N^2(C^7\ddot{H}^6O)^3$
Hydrobromosalicylamide .	$C^{21}H^{15}Br^3N^2O^3$	$= N^2(C^7\ddot{H}^3BrO)^3$
Hydrochlorosalicylamide .	$C^{21}H^{15}Cl^3N^2O^3$	$= N^2(C^7\ddot{H}^3ClO)^3$

Glycosine, $N^2(C^{\prime\prime\prime\prime}H^2)^3$, from glyoxal (ii. 919), may also be regarded as a hydramide, or rather hydramine.

The aldehydes of the fatty acids (acetic aldehyde and its homologues) do not appear to yield compounds of this class.

The hydramides are crystalline solids, insoluble in water, soluble in alcohol, not volatile without decomposition, and not possessing alkaline properties; but when left in contact with strong caustic alkalis (Fownes), or when simply raised to a high temperature (Bertagnini), they are converted into isomeric compounds possessing strong basic properties, *e. g.* furfuramide into furfurine, hydrobenzamide into amarine. The difference of constitution between these bases and the corresponding hydramides is not precisely understood; but Borodine has shown that amarine contains a larger number of atoms of replaceable hydrogen than its isomer, hydrobenzamide. (See HYDROBENZAMIDE.)

Some hydramides, *e. g.* hydrobenzamide and hydrosalicylamide, are decomposed by acids, yielding ammonia and the corresponding aldehydes. By sulphydric acid they are converted into sulphuretted aldehydes (thialdides), *e. g.* furfuramide into thiofurfol:

$$\underset{\text{Furfuramide.}}{(C^5H^4O)^3N^2} + 3H^2S = 2NH^3 + \underset{\text{Thiofurfol.}}{3C^5H^4OS}.$$

HYDRANZOTIN. $C^2H^4N^2S^4$. *Disulphide of Sulphocarbammonium, Dihydrosulphuretted Sulphocyanogen* (Zeise, Ann. Ch. Pharm. xlviii. 95; Debus, *ibid.* lxxiii. 27).—When chlorine-water is added by small portions to a solution of sulphocarbamate of ammonium in 5 or 6 pts. of water, the liquid being well shaken, and care being taken to avoid an excess of chlorine, this body is produced, as a flocculent crystalline precipitate, which must be washed with cold water till the wash-water no longer reddens ferric salts, and dried in vacuo. It is also produced by heating an aqueous solution of sulphocarbamate of ammonium, first with a large excess of sulphuric or hydrochloric acid, then with a ferric salt.

Hydranzotin, when first prepared, is colourless, with a nacreous lustre, and inodorous; but after a while it gives off sulphuretted hydrogen. It is very sparingly soluble in *water*, dissolves without alteration in *alcohol*, and is dissolved by *ether* in very large quantity, but with some alteration, the solution reddening litmus. An alcoholic solution of *potash* dissolves a considerable portion of it, yielding a neutral liquid, which, when boiled, yields sulphide of potassium, sulphocyanate of potassium and sulphur.

The same transformation takes place on boiling the solution of the compound in absolute alcohol:

$$C^2H^4N^2S^4 = H^2S + 2CHNS + S.$$

The compound is not decomposed by trituration with oxide of lead, unless the mixture is heated. By *dry distillation* it yields sulphide of carbon, accompanied by a little sulphydric acid, and sulphydrate and sulphocarbonate of ammonium, leaving a small quantity of a black substance. It is not perceptibly decomposed by sulphuric or hydrochloric acid.

HYDRARGAMYL, HYDRARGETHYL, &c. See MERCURAMYL, MERCURETHYL, &c.

HYDRARGYLLITE. See GIBBSITE (ii. 838).

HYDRARGYRUM. Syn. with MERCURY.

HYDRASTINE. An alkaloïd discovered by J. D. Perrins (Pharm. J. Trans. [2] iii. 546) in the root of *Hydrastis Canadensis*, in which it exists to the amount of about

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appears also to have been previously noticed in iii. 112). It is very soluble in dilute mineral e berberine but sparingly: it may therefore be c mother-liquors remaining after the separation se, the alcohol is distilled off, and the liquid, mixed with ammonia till the resulting preci- in, no longer disappears on stirring. If the ess of ammonia, hydrastine is precipitated as a starch under the microscope, and gradually be- isation from alcohol, with help of animal char- , four-sided prisms, becoming dull when dry. *er*, but dissolves easily in *alcohol*, *ether*, *chloro-* d directly from the pulverised root by heating lvents, neither of which will dissolve berberine. ittle above 100°; it has a sharp bitter taste, but g nitric acid colours it yellowish-brown; with m, or peroxide of lead, it assumes a brick-red xed with chlorine-water acquire a blue fluo-

ost part soluble.

to compounds containing oxygen and hydrogen, y be supposed to exist, in the form of water;

)	Hydrate of sodium .	$Na^2O.H^2O$
)	Sulphuric acid . .	$SO^3.H^2O$
	Crystallised alum	$Al^2KS^2O^8.6H^2O$
)	Crystallised glucose .	$C^6H^{12}O^6.H^2O$
)		

either as compounds of water with anhydrous sodium and sulphuric acid above given, the one case and of a base in the other; or as plex molecule of water, nH^2O, by the replace- ydrogen by a radicle either positive or negative:

Acid.	*Alcoholic.*
Nitric acid. $\left.\begin{matrix}NO^2\\H\end{matrix}\right\}O$	Ethylic alcohol. $\left.\begin{matrix}C^2H^5\\H\end{matrix}\right\}O$
Sulphuric acid. $\left.\begin{matrix}(SO^2)''\\H^2\end{matrix}\right\}O^2$	Glycol. $\left.\begin{matrix}(C^2H^4)''\\H^2\end{matrix}\right\}O^2$
Orthophosphoric acid. $\left.\begin{matrix}(PO)'''\\H^3\end{matrix}\right\}O^3$	Glycerin. $\left.\begin{matrix}(C^3H^5)'''\\H^3\end{matrix}\right\}O^3$
Glycero-sulphuric acid. $\left.\begin{matrix}(SO^2)''\\(C^3H^5)'''\\H^3\end{matrix}\right\}O^4$	Triethylenic alcohol. $\left.\begin{matrix}(C^2H^4)^3\\H^2\end{matrix}\right\}O^4$
Pyrophosphoric acid. $\left.\begin{matrix}(P'''O)^2\\H^4\end{matrix}\right\}O^5$	Tetrethylenic alcohol. $\left.\begin{matrix}(C^2H^4)^4\\H^2\end{matrix}\right\}O^5$
Glycerotartaric acid. $\left.\begin{matrix}(C^4H^2O^2)^{IV}\\(C^3H^5)'''\\H^3\end{matrix}\right\}O^6$	Pentethylenic alcohol. $\left.\begin{matrix}(C^2H^4)^5\\H^2\end{matrix}\right\}O^6$
	Triglycerin. $\left.\begin{matrix}(C^3H^5)^3\\H^3\end{matrix}\right\}O^7$

d column and the last four in the fourth, afford an half the typic hydrogen is replaced by an

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acid or alcoholic radicle: other examples of such hydrates (which may also be regarded as anhydrides, inasmuch as they are formed by dehydration of normal hydrates) will be found under ETHYLENE, HYDRATES of (ii. 576), GLYCERYL, HYDRATES of (ii. 894), GLYCEROTARTARIC ACIDS (ii. 893).

Metallic hydrates retain the elements of water with various degrees of force. Hydrate of copper parts with its water at a very moderate heat; hydrate of calcium, at a strong red heat; while the hydrates of potassium and sodium are not decomposed by the strongest heat that can be applied to them. Hydrated acids likewise exhibit various degrees of stability. Tribasic phosphoric acid, $P^2O^5.3H^2O$ or PH^3O^4, gives off part of its water at a red heat, being converted first into the dibasic acid, $P^2O^5.2H^2O$, and ultimately into the monobasic acid, $P^2O^5.H^2O$, which resists further decomposition. The hydrates of volatile acids exhibit remarkable relations to heat. Under given circumstances of pressure and temperatures, there is for each acid a certain proportion of water which forms a stable compound, a weaker acid under that pressure and temperature giving off water, and a stronger acid giving off acid, till the most stable compound remains behind (Roscoe, Chem. Soc. Qu. J. xiii. 146). See SULPHURIC ACID, NITRIC ACID, CHLORHYDRIC ACID, &c.

The hydrates of the stronger acids and bases may be formed by direct combination of the anhydrous base or acid (anhydride) with water, the combination being sometimes attended with great evolution of heat, as in the case of sulphuric acid, baryta, and lime. In other cases, the hydrate cannot be formed directly, and in others again the union takes place but slowly. Acetic anhydride may be left in contact with water for several days without dissolving in it; but on the application of heat, it gradually dissolves. Among organic acids, it is found that dibasic acids are formed by the direct union of the anhydride and water, and that the hydrate may be decomposed by heat: this is the case with succinic and tartaric acids; whereas the hydrates of monobasic acids, such as acetic acid, cannot be thus decomposed by heat alone. This difference is probably related to the fact, that the molecule of a dibasic acid, like succinic acid, $\left.\begin{matrix}(C^4H^4O^4)'' \\ H^2\end{matrix}\right\}O^2$, contains a sufficient number of atoms of basic hydrogen to form water; whereas the molecule of a monobasic acid, such as acetic acid, $\left.\begin{matrix}C^2H^3O \\ H\end{matrix}\right\}O$, does not.

The hydrates of lithium, sodium, potassium, barium, strontium, and thallium, are easily soluble in water, forming strongly alkaline solutions; hydrate of calcium is moderately soluble; the other metallic hydrates are insoluble or nearly so; those of magnesium, mercury, lead, and silver are, however, sparingly soluble. The hydrates of the more acid or chlorous radicles are all more or less soluble in water, with the exception of certain organic acids of high atomic weight, such as the higher members of the fatty acid series, palmitic, stearic, cerotic acid, &c.: these bodies dissolve readily in alcohol and in ether. Similar remarks apply to the alcoholic hydrates.

In many hydrated compounds, part or the whole of the oxygen and hydrogen appears actually to exist as water, as in bases, salts, &c., containing water of crystallisation: *e.g.* crystallised *hydrate of barium*, $Ba''H^2O^2.8H^2O$, *crystallised alum* $(SO^4)^2Al'''K.12H^2O$. Water can unite in this manner with salts and other bodies in the most various proportions, sometimes one molecule of the salt being united with several molecules of water, as in the instances above given, and sometimes, though less frequently, one molecule of water with two or more molecules of the salt; sometimes in more complex proportions, as in crystallised *nitrate of strontium*, $Sr''(NO^3)^2.5H^2O$.

Water thus united with a salt or other body is for the most part expelled at 100° C.: some salts, however, retain part of their water with greater tenacity than the rest; thus crystallised sulphate of zinc, $Zn''SO^4.7H^2O$, gives off 6 at. water at 100°, but retains the seventh atom till heated to 238°; sulphate of magnesium, $Mg''SO^4.7H^2O$, exhibits a similar deportment. Moreover, this last atom of water, which by its greater stability appears to be more intimately united with the salt than the rest, may be replaced by a molecule of another salt, as sulphate of potassium or ammonium:

Crystallised sulphate of zinc . . .	$Zn''SO^4.H^2O$ + 6 aq.
Sulphate of zinc and potassium . . .	$Zn''SO^4.K^2SO^4$ + 6 aq. or $Zn''K^2(SO^4)^2$ + 6 aq.

Water united with a salt in this manner is called by Graham *constitutional water*, to distinguish it from water of crystallisation. Liebig distinguishes these hydrated compounds, *e.g.* $Zn''SO^4.H^2O$, by the term *kalhydrates*.

HYDRAULIC LIMESTONE. See LIMESTONE.

HYDRIDES. This term is applied chiefly to the compounds of hydrogen with metals, alcohol-radicles, and organic acid-radicles, *e.g.* hydride of copper, Cu^2H^2; hydride of ethyl, $C^2H^5.H$; hydride of benzoyl, $C^7H^5O.H$.

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Metallic Hydrides. A few only of these compounds are known. The most important are the gaseous hydrides of *arsenic* and *antimony*, AsH^3 and SbH^3 (i. 322. 371), formed on the ammonia type. *Phosphoretted hydrogen*, or *phosphamine*, PH^3, belongs to the same class. There is also a solid hydride of arsenic, supposed to have the composition AsH^1, produced when water is electrolysed by a strong current, with metallic arsenic for the negative pole. It is doubtful whether a hydride of *bismuth* exists, analogous to the gaseous arsenides of arsenic and antimony. Hydride of *copper*, Cu^2H^2, produced by the action of hypophosphorous acid on aqueous cupric sulphate, is remarkable for its reaction with hydrochloric acid, the products of which are cuprous chloride, Cu^2Cl^2, and free hydrogen (ii. 66). A hydride of *iron* has been obtained by Wanklyn and Carius (Ann. Ch. Pharm. cxx. 69) by acting on ferrous iodide with zinc-ethyl. It is a black metallic powder, which gives off hydrogen when immersed in water.

Hydrides of Alcohol-radicles.—1. Of the radicles C^nH^{2n+1}. These hydrides are the homologues of marsh-gas, or hydride of *methyl*, $CH^3.H$, the lowest term of the series. The hydrides of *ethyl*, *trityl*, and *tetryl* are gaseous at ordinary temperatures; the rest, up to $C^{15}H^{32}$, the highest yet obtained, are liquids of more or less disagreeable odour, burning with a slightly smoky flame, and regularly increasing in specific gravity, vapour-density, and boiling-point, as their atomic weights become greater. The highest terms of the series will doubtless be found to be solid waxes and paraffins.

Hydride of *methyl* (marsh-gas) is produced by the putrefaction and dry distillation of organic bodies, and by distilling acetic acid or acetone with excess of potash (i. 13). Hydride of *ethyl* is obtained by the decomposition of ethyl itself, which under certain circumstances splits up into this compound and ethylene (ii. 565):

$$2C^2H^5 = C^2H^5.H + C^2H^4;$$

also when iodide of ethyl is decomposed by zinc in presence of water:

$$2C^2H^5I + H^2O + Zn^2 = 2(C^2H^5.H) + Zn^2I^2O.$$

Hydride of *tetryl*, $C^4H^9.H$, is produced by heating tetrylic alcohol with chloride of zinc, and hydride of *amyl*, $C^5H^{11}.H$, together with several of its higher homologues, by similar treatment of amylic alcohol (p. 147).

Hydride of amyl and some of its homologues are also contained, together with other hydrocarbons, in the light oils resulting from the distillation of Boghead coal (Gr. Williams, Phil. Trans. 1857, p. 727; Jahresber. 1857, p. 437.—Chem. Soc. J. xv. 130), and of Wigan cannel coal (Schorlemmer, Chem. Soc. J. xv. 419): for the mode of separating them, see p. 146. Many of these alcoholic hydrides are also contained in American petroleum or earth-oil (which indeed appears to consist almost entirely of them), hydride of *hexyl*, C^6H^{14}, constituting the principal portion (Pelouze and Cahours, Ann. Ch. Pharm. cxxiv. 289; cxxvii. 196; cxxix. 87). They are separated by fractional distillation, and purified by successive treatment with sulphuric acid and carbonate of sodium, desiccation with anhydrous chloride of calcium, distillation over sodium, and final rectification. In this manner, Pelouze and Cahours have obtained twelve of these hydrides, included under the general formula C^nH^{2n+2}, from hydride

Specific Gravities and Boiling Points of Alcoholic Hydrides, C^nH^{2n+2}.

	Specific gravities.			Boiling points.		
	Pelouze and Cahours.	Schorlemmer.	Wurtz.	Pelouze and Cahours.	Schorlemmer.	Wurtz.
Hydrides of						
Tetryl C^4H^{10} .	. .	. .	. .	little above 0°		
Amyl C^5H^{12} .	0·628 at 17°	0·636 at 17°	. .	30°	39°— 40°	28°— 30°
Hexyl C^6H^{14} .	0·669 „ 16	0·678 „ 15·5	. .	68	68 — 70	60 — 64
Heptyl C^7H^{16} .	0·699 „ 15	0·709 „ 17·5	. .	92— 94	98 — 99	
Octyl C^8H^{18} .	0·726 „ 15	0·719 „ 17	0·728 at 0°	116—118	119 —120	115 —118
Nonyl C^9H^{20} .	0·741 „ 15	. .	. .	136—138	. .	134 —137
Decatyl $C^{10}H^{22}$.	0·757 „ 15	. .	0·753 „ 0	160—162	. .	155 —157
Endecatyl $C^{11}H^{24}$	0·765 „ 16	. .	. .	180—184		
Dodecatyl $C^{12}H^{26}$	0·776 „ 20	. .	. .	196—200		
Tridecatyl $C^{13}H^{28}$	0·792 „ 20	. .	. .	216—218		
Tetradecatyl $C^{14}H^{30}$ . .	. .	. .	. .	236—240		
Pentadecatyl $C^{15}H^{32}$ . .	. .	. .	. .	255—260		

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of tetryl, C^4H^9, boiling at a few degrees above 0°, to hydride of pentadecatyl, C
boiling between 255° and 260°. The oil also yields a quantity of liquid boiling
300°, and doubtless containing some of the higher terms of the same series. More
in boring for it, large quantities of gas escape, exhibiting the characters of marsh
hence it is probable that, in the great geological changes which have given rise t
separation of this remarkable liquid, the whole series of homologous alcohol-hyd
C^nH^{2n+2} has been produced, from marsh-gas up to the highest paraffins.

The preceding table (p. 181) exhibits the specific gravities and boiling-points o
alcoholic hydrides obtained from these several sources. The vapour-densities hav
been determined in all cases, and found to agree nearly with those calculated fro
respective formulæ for a condensation to 2 volumes. Wurtz's determinations
made on the hydrides obtained by the decomposition of amylic alcohol; Schorlem
on those from cannel-naphtha; those of Pelouze and Cahours, on the hydrides
American petroleum.

These alcoholic hydrides are very stable compounds. They are little, if at all,
upon by fuming *nitric acid*, strong *sulphuric acid*, or *bromine*; but *chlorine* co
them all into the corresponding alcoholic chlorides $C^nH^{2n+1}Cl$.

Each alcoholic hydride of the series $C^nH^{2n+1}.H$ (except hydride of meth
identical in composition with a radicle, simple or mixed, belonging to the same s
thus—

Hydride of Ethyl	$C^2H^5.H$	= Methyl	$CH^3.CH^3$
,, Trityl	$C^3H^7.H$	= Methyl-ethyl	$CH^3.C^2H^5$
,, Tetryl	$C^4H^9.H$	= Ethyl	$C^2H^5.C^2H^5$
,, Amyl	$C^5H^{11}.H$	= Ethyl-trityl	$C^2H^5.C^3H^7$
		= Methyl-tetryl	$CH^3.C^4H^9$

and generally:

$$C^{2m}H^{4m+1}.H = C^m H^{2m+1}.C^mH^{2m+1}$$

$$C^{2m+1}H^{4m+3}.H = C^mH^{2m+1}.C^{m+1}.H^{2m+3}$$

The question, therefore, arises: are the members of the two series, the al
radicles and their hydrides, identical or only isomeric? Soon after the isolation
alcohol-radicles by Frankland and Kolbe, in 1849, Laurent and Gerhardt pronou
the opinion that these compounds were the homologues of marsh-gas. This view
not been generally received as correct (see ALCOHOL-RADICLES i. 96); but rec
Schorlemmer (Chem. Soc. J. xv. 425) has endeavoured to solve the questi
examining the products obtained by the action of chlorine on the radicles and
isomeric hydrides. He finds that ethyl-amyl, $C^2H^5.C^5H^{11}$, treated with chlorine,
a chloride, $C^7H^{15}Cl$, agreeing in composition, as well as in boiling point and
physical properties, with that which is produced by the action of chlorine on hy
of heptyl (p. 144). From amyl, $C^{10}H^{22}$, Schorlemmer obtained, in like manner, a chl
$C^{10}H^{21}Cl$, boiling at about 200°, which he regards as identical with that which
obtained by the action of chlorine on hydride of decatyl, $C^{10}H^{21}.H$. From
results, Schorlemmer concludes that no chemical difference exists between the alc
hydrides and the radicles, at least among the higher members of the series.

2. *Hydrides of the Alcohol-radicles* C^nH^{2n-7}.—Two compounds of this serie
known, viz:—

Hydride of Phenyl (Benzene)	C^6H^6	=	$C^6H^5.H$
Hydride of Benzyl (Toluene)	C^7H^8	=	$C^7H^7.H$

Both these hydrides are contained in the light oils obtained by the distillati
coal. When treated with strong nitric acid, they yield substitution-products, in the fo
heavy oils, the formation of which affords the means of separating these hydroca
from those of other series with which they may be mixed (p. 146). The prepar
and properties of these hydrides have already been fully described (i. 542, 573).

The hydrides of alcohol-radicles of other series have not yet been obtained.

Hydrides of Acid-radicles: The aldehydes, referred to the hydrogen-type
constitute this class of compounds, *e.g.* acetic aldehyde, $C^2H^4O = C^2H^3O.H$; be
aldehyde (bitter-almond oil), $C^7H^6O = C^7H^5O.H$ (see ALDEHYDES, i. 110).

HYDROALOETIC ACID. An acid formed from aloetic or chrysammic ac
the action of water and stannous chloride. A dark violet powder is then prod
which at 120° contains, according to Mulder, $SnO^2.C^{14}H^4N^2O^{11}$. This stannic
treated with potash, gives off ammonia and assumes a blue-violet colour; and when h
with strong nitric acid, gives off nitrous fumes, turns red, and yields, first aloetic
then, after longer boiling, chrysammic acid (Mulder, Ann. Ch. Pharm. lxxii. 26

HYDROAPATITE. A hydrated phosphate of calcium, containing fluorine,
in milk-white, translucent, warty concretions, in clefts of a ferruginous-
laceous rock, imbedded in a black slate, near St. Girons (Ariège) in the Pyre
It scratches fluor-spar, but is scratched by steel. Specific gravity = 3·16. It co

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40·00 per cent. P^2O^5, 52·35 CaO, 3·36 F, and 5·30 water, together with 6·42 ferric phosphate, agreeing nearly with the formula $3Ca^3P^2O^8.CaF^2.3H^2O$. (Damour, Ann. Min. [5] x. 65; Jahresber. 1856, p. 874.)

HYDROBENZAMIDE. $C^{21}H^{18}N^2$. *Tribenzylene-diamide, Hydride of Azobenzoyl.* (Laurent, Ann. Ch. Phys. [2] lxii. 23; lxvi. 18; [3] i. 300.—Bertagnini, Ann. Ch. Pharm. lxxxviii. 127.)—This compound, which may be regarded as a tertiary diamide, $N^2(C^7H^6)^3$, in which the hydrogen is completely replaced by the diatomic radicle benzylene, is produced by the action of ammonia on hydride of benzoyl (bitter almond oil). When rectified bitter almond oil (boiling at 180°) is left in contact with aqueous ammonia for a few days, or for only six or eight hours if the liquid be previously heated to the boiling point of the ammoniacal solution, a crystalline mass is formed, which must be broken up, washed rapidly with ether to remove adhering oil, and then dissolved in boiling alcohol, which leaves undissolved a number of secondary products resulting from the action of the ammonia on hydrocyanic acid contained in the bitter almond oil. According to Ekman (Ann. Ch. Pharm. cxii. 151), hydrobenzamide may be obtained in fine crystals by mixing bitter almond oil with an equal volume of ether and strong aqueous ammonia, and leaving the mixture at rest.

Hydrobenzamide separates from its alcoholic solution in colourless octahedrons with a rhombic base, truncated on their longer lateral edges. Angles of the terminal edges, 130° and 122°; angles of the lateral edges, 84° 50′. It is insoluble in water, very soluble in alcohol and ether. The crystals are destitute of taste and odour, but the alcoholic solution has a taste of burnt almonds. The crystals melt at 110°, forming a thick oil, which has a sweet taste, and solidifies after a while to an opaque brown mass.

Decompositions.—1. Hydrobenzamide, when heated in the air, takes fire, and burns with a not unpleasant odour (Laurent).—2. Between 120° and 130° it changes in three or four hours into amarine (Bertagnini).—3. By *dry distillation*, it yields lophine and a strong-smelling volatile oil, leaving a small quantity of carbonaceous matter (Laurent).—4. When the alcoholic solution is continuously boiled, ammonia escapes, and on evaporating the alcohol, bitter almond oil remains (Laurent).—5. Boiled with aqueous *chromic acid*, it yields a large quantity of benzoic acid (Fownes, Phil. Trans. 1845, 263).—6. With *acids*, even at ordinary temperatures, it yields bitter almond oil and the ammonia-salt of the acid (Laurent, Fownes).—7. Boiled with *potash-ley*, it changes gradually and without perceptible decrease of weight, into amarine, only a faint odour of bitter almond oil being evolved (Fownes). Boiled with alcoholic potash, it gives off a small quantity of ammonia and bitter almond oil (Laurent).—8. When it is fused with *hydrate of potassium*, the mass becomes first light yellow, then dark yellow, and ultimately brown and black; and if slowly heated, gives off nothing but ammonia: if the heat be continued, there is given off, besides ammonia, a mixture of about 4 vol. hydrogen gas to 1 vol. carburetted hydrogen. The black residue contains carbonate and cyanide of potassium, benzostilbin, benzolone, and a small quantity of a yellow oil, which thickens and becomes viscid on exposure to the air; the mass, which has then become dark yellow, contains nothing but benzostilbin and a considerable quantity of the yellow oil (Rochleder, Ann. Ch. Pharm. lxi. 89).—9. Heated with *potassium*, it yields a red fusible mass and a small quantity of charcoal (Laurent).—10. When *sulphydric acid* is passed through the alcoholic solution, sulphide of benzylene is produced (Cahours).—11. A solution of hydrobenzamide in absolute alcohol mixed with a solution of *sulphurous anhydride* in absolute alcohol, deposits, after a while, a white precipitate of sulphite of benzoyl and ammonium, $C^7H^5(NH^4)SO^3$, and the remaining solution yields by distillation, first alcohol, then diethyl-benzylenic ether, $\left.\begin{matrix}(C^7H^6)''\\(C^2H^5)^2\end{matrix}\right\}O^2$ (R. Otto, Ann. Ch. Pharm. cxii. 305).—12. When hydrobenzamide is saturated with *hydrochloric acid gas*, a compound free from nitrogen slowly volatilises, whilst a non-volatile azotised compound remains behind, which is not altered by ether, but is dissolved by alcohol, with separation of sal-ammoniac. This compound (hydrochlorate of hydrobenzamide) is resolved by water into sal-ammoniac and hydride of benzoyl:

$$C^{21}H^{18}N^2.2HCl + 3H^2O = 2NH^4Cl + 3C^7H^6O,$$

and by absolute alcohol into sal-ammoniac and diethyl-benzylenic ether:

$$C^{21}H^{18}N^2.2HCl + 6C^2H^6O = 2NH^4Cl + 3\left[\left.\begin{matrix}(C^7H^6)''\\(C^2H^5)^2\end{matrix}\right\}O^2\right].$$

(Ekman, Ann. Ch. Pharm. cxii. 151; Jahresber. 1859, p. 317.—Lieke, ibid. 318).

Hydrochlorate of hydrobenzamide, heated to 160°—230°, yields, besides hydrochloric acid, an oily distillate, containing benzonitrile and chloride of benzyl, C^7H^7Cl (i. 573), and leaves a red-brown residue, which is separated, by digestion with alcohol at ordinary

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temperatures, into a brown solution (A) and yellow flocks. The latter dis mixture of alcohol and chloroform, forming a solution which deposits two mo of lophine, $C^{21}H^{16}N^2$; the one crystallising in needles which melt at 230°, th needles which melt at 170° (see LOPHINE). The brown solution (A) yields two modifications of lophine just mentioned; secondly, a base, probably melting at 90°; thirdly, a base, $C^{21}H^{20}N^2$, which melts at 100°, forms a $C^{21}H^{20}N^2.C^2H^2O^4$, crystallising from alcohol in nacreous laminæ, and a plat $C^{21}H^{20}N^2.HCl.PtCl^2.2H^4O$, in microscopic prisms; fourthly, another modificat same base, whose platinum-salt is anhydrous; and fifthly, an oily base, forming a hydrochlorate, which melts at 220°, dissolves easily in water an and crystallises in six-sided prisms. (Ekman, *loc. cit.*—Kühn, N. Jahrb. P 292; Jahresber. 1861, p. 404.)

13. Hydrobenzamide heated with 2 at. *iodide of ethyl* to 80°—100°, yiel brown viscid mass, which, after purification by solution in alcohol, precip water, &c., is found to consist of di-iodide of tribenzylene-diethyl-dia

$[(C^7\ddot{H}^6)^3(C^2H^5)^2N^2]^2I^2$; and the alcoholic solution of this iodide, treated

of silver or hydrate of lead, yields the base $C^{25}H^{28}N^2O = [(C^7\ddot{H}^6)^3(C^2H^5)^2N^2$ base, again treated with iodide of ethyl, does not yield any distinct (Borodine, Ann. Ch. Pharm. cv. 257.)

Amarine, isomeric with hydrobenzamide, behaves differently with iodide yielding hydriodate of diethylamarine, $C^{21}H^{16}(C^2H^5)^2N^2.HI$, from which, by h potash, diethylamarine itself, $C^{21}H^{16}(C^2H^5)^2N^2$, may be obtained; and this b treated with iodide of ethyl, yields another base, which forms crystalline appears to contain a larger proportion of ethyl. This base is likewise acte iodide of ethyl, yielding a hydriodate just like the former. Hence B concludes that amarine contains at least 3 at. H, replaceable by ethyl, and it provisionally by the formula $N\begin{cases}N(C^7H^5)^3H.\\H^2\end{cases}$

Chloride of Hydrobenzamide, $C^{21}H^{18}N^2Cl^2$ (Th. Müller, Ann. C cxi. 144; Jahresber. 1859, p. 315), is produced by passing dry chlorine hydrobenzamide, which then takes up 19·5 per cent. chlorine, and melts t yellow liquid. It is decomposed by water, yielding sal-ammoniac, hydrochlor an oily mixture of hydride of benzoyl and benzonitrile, boiling between 180°

$$\underset{\text{Chloride of hydrobenzamide.}}{C^{21}H^{16}N^2Cl^2} + 2H^2O = \underset{\text{Hydride of benzoyl.}}{2C^7H^6O} + \underset{\text{Benzonitrile.}}{C^7H^5N} + NH^4Cl + HC$$

By anhydrous ether it is resolved into sal-ammoniac, and a mixture of b with an oily body which boils at 183°, and has the composition of chloroh mide (see below), but differs from that substance by its ready decomposibilit into benzonitrile and hydride of benzoyl.

Chloride of hydrobenzamide heated to 180°—200° is resolved into hydroc chlorohydrobenzamide, $C^{21}H^{17}ClN^2$, which distils over as a colourless oil, and which solidifies on cooling, and is resolved, by successive treatment with w and alcohol, into the following compounds:

The *aqueous* solution deposits on cooling a white powder, which sepa alcohol in hard granular crystals, consisting of $C^{21}H^{17}ClN^2.HCl$ or $C^{21}H^{18}N^2$ water the same compound crystallises with 1 at. H^2O. Ammonia added to t

throws down [? as a hydrate] the base $C^{28}H^{24}N^2 = N^2(C^7\ddot{H}^6)^4$, which may tetrabenzylene-diammonium. The chloroplatinate, $C^{28}H^{24}Cl^2N^2.PtC$ soluble.

The *ethereal* solution deposits crystalline needles insoluble in water, su 300°, and having the composition $C^{28}H^{21}N^3$.

The *alcoholic* solution yields crystals insoluble in water and in ether, and when dried over oil of vitriol, $C^{28}H^{22}N^3.HCl.2H^2O$. If the base be separate salt by ammonia, and redissolved in hydrochloric acid, the solution yields b tion a basic hydrochlorate, $2C^{28}H^{22}N^3.HCl.2H^2O$. The chloroplatinate, wh yellow, contains $2(C^{28}H^{22}N^3.HCl).PtCl^4$ (platinum, by experiment, 17·4 pe calculation, 17·9).

Chlorohydrobenzamide. $C^{21}H^{17}ClN^2$. (Th. Müller, *loc. cit.*)—Wh of hydrobenzamide is heated to 180°—200°, this compound distils over as a oil, heavier than water, and having a pungent odour of chlorine and b together. It dissolves easily in alcohol and in ether, and is slowly deco water, with formation of hydrochloric acid. When left in contact, for with a mixture of *nitric* and *sulphuric acids*, it forms a solution from w throws down crystallisable nitrobenzonitrile, $C^7H^4(NO^2)N$.

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Chloronitro-hydrobenzamide. $C^{21}H^{15}Cl(NO^2)N^2$. (Müller, *loc. cit.*)—This compound is formed when chlorohydrobenzamide is left for 24 hours in contact with strong *nitric acid*, and is precipitated by water from the acid solution, as an oily very pungent liquid. It is soluble in alcohol, and the solution is decomposed by sulphide of ammonium, yielding benzonitrile and sulphobenzamide:

$$\underset{\text{Chloronitro-hydrobenz-amide.}}{C^{21}H^{15}Cl(NO^2)N^2} + 3H^2S = 2\underset{\text{Benzonitrile.}}{C^7H^5N} + \underset{\text{Sulphobenz-amide.}}{C^7H^7NS^2} + 2H^2O + HCl + S^2.$$

Hydrobenzile. $C^{14}H^{12}O$. (Zinin, J. pr. Chem. xxxiii. 35.)—A product of the action of sulphide of ammonium on benzile ($C^{14}H^{10}O^2$). It is insoluble in water, soluble in alcohol and ether, and crystallises from these solutions in the shape of concavo-convex lenses. The crystals melt at 47°, forming a colourless liquid, which distils without alteration, and solidifies in a crystalline mass at 42°. They have the smell of bitter almonds, and a saccharine pungent taste. They dissolve readily in sulphuric acid, and are precipitated therefrom by water. They are slowly attacked by chlorine, and not sensibly altered by boiling potash.

Hydrobenzoïn. $C^{14}H^{14}O^2$. (Zinin, Ann. Ch. Pharm. cxxiii. 125.)—A compound produced by the action of nascent hydrogen on benzoyl-hydride (bitter almond-oil), and containing the elements of 2 molecules of that compound ($C^{14}H^{12}O^2$), and 1 molecule of hydrogen, H^2. To prepare it, 4 pts. of bitter almond oil free from prussic acid are dissolved in 6 pts. alcohol of 85 per cent.; the solution is mixed with 4 pts. alcohol previously saturated with hydrochloric acid gas; and one pt. of finely-granulated zinc is carefully added, so that it may dissolve without perceptible evolution of hydrogen. When the reaction is finished, the liquid is heated to the boiling point, mixed after cooling with a small quantity of ether (to remove a body which adheres to the zinc and retards the action) and with 1 pt. more of alcohol saturated with hydrochloric acid gas, then heated to complete the reaction, and mixed with a quantity of water three or four times as great as that of the bitter almond oil taken. Hydrobenzoïn then separates as an oily body, which soon solidifies in a crystalline mass, and may be purified by washing in water, pressure between bibulous paper (to remove an acrid oil), and recrystallisation from alcohol (or if somewhat impure, previously from ether). It is thus obtained in large rhombic plates, which melt at 130°, and boil above 300°. When gently heated with 2 pts. nitric acid of specific gravity 1·36, it is converted, without any evolution of red vapours or formation of secondary products, into pure benzoïn; with stronger nitric acid, benzil is obtained. It is not attacked by potash, either aqueous or alcoholic, even at the boiling heat.

Hydroberberine. $C^{20}H^{21}NO^4$. (Hlasiwetz and Gilm. Ann. Ch. Pharm. Suppl. ii. 191; Rép. Chim. pure, 1863, p. 426.)—A base produced by the action of nascent hydrogen on berberine, as first observed by Hlasiwetz (Rép. Chim. pure, 1862, p. 367). It is obtained by boiling in a flask, provided with a condensing tube to cause the vapours to flow back, a mixture of 6 pts. berberine, 100 pts. water, 10 pts. distilled sulphuric acid, 20 pts. glacial acetic acid, a quantity of granulated zinc, and a few pieces of platinum foil. The liquid gradually loses its colour, and as soon as the froth exhibits a wine-yellow colour, which it does after boiling for an hour or two, the action is stopped, the liquid filtered, any crystalline deposits that may have formed are dissolved in dilute sulphuric acid, and an excess of ammonia is added after cooling. Hydroberberine is then obtained as a bulky yellowish deposit, which must be collected on a filter, washed, dried at a gentle heat, then pulverised, boiled in alcohol, and purified by repeated crystallisation from alcohol. Instead of precipitating the base by ammonia, it may be advantageously obtained as a hydrochlorate, by adding common salt to the original solution. The hydrochlorate is then almost wholly deposited in the form of a crystalline powder.

Hydroberberine may also be prepared by acting on berberine with sodium-amalgam, but it is then yellow and more difficult to purify.

Hydroberberine is deposited from a hot alcoholic solution, in small shining granular crystals, or flattened needles, which are colourless or slightly yellowish, and appear to belong to the monoclinic system. It differs from berberine, $C^{20}H^{17}NO^4$ (the formula lately determined by Perrins, Chem. Soc. J. xv. 339), by four additional atoms of hydrogen, and may be reconverted into that compound by the action of nitric acid. On dissolving it in a mixture of equal volumes of hydrochloric acid and alcohol, and dropping in nitric acid diluted with alcohol, the liquid becomes coloured, and deposits crystals of hydrochlorate of berberine.

Hydrochlorate of Hydroberberine. $C^{20}H^{21}NO^4.HCl$.—Crystals of hydroberberine spread upon a watch-glass, under a bell-jar within which hydrochloric acid is evolved, are converted into a white powder, consisting of the hydrochlorate, soluble in warm water, and crystallising in laminæ on cooling. The salt may also be obtained by

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dissolving the base in hot hydrochloric acid; the solution on cooling forms a jelly, which is gradually transformed into crystals. It is more soluble in alcohol than in water. Its solutions yield copious precipitates with *chloride of platinum;* from a warm alcoholic solution, the platinum-salt is more gradually deposited in orange-yellow crystalline grains, consisting of $2(C^{20}H^{21}NO^4.HCl).PtCl^4$.

The *hydrobromate* and *hydriodate* are white, crystalline, and very slightly soluble.

The *nitrate*, which is also crystalline and very slightly soluble, is seldom obtained pure by dissolving the base in nitric acid, because the acid decomposes it; better by mixing a hot, very dilute solution of the sulphate with nitrate of sodium.—The *oxalate* crystallises in small rhombic plates, the *phosphate* in fine rhombic plates.

Sulphates of Hydroberberine. The neutral sulphate, $(C^{20}H^{21}NO^4)^2.H^2SO^4$, is obtained by dissolving an excess of the base in very dilute sulphuric acid. The liquid then deposits needles which fill it entirely, and after being expressed and purified by crystallisation, are very soluble in water, and contain a certain quantity of water, which they lose by exposure to the air; they likewise invariably contain a little free acid.

When the base is dissolved in a slight excess of acid, large transparent rhombohedrons are obtained, approaching nearly to the cube; they give off water when exposed to the air, and cannot be dissolved in water without decomposition. They appear to be a mixture of the neutral and acid sulphates, containing $4C^{20}H^{21}NO^4.3SH^2O^4.4H^2O$, or $\left.\begin{matrix}(C^{20}H^{21}NO^4)^2.SH^2O^4\\ 2(C^{20}H^{21}NO^4.SH^2O^4)\end{matrix}\right\}.4H^2O$.

A moderately dilute solution of this salt mixed with excess of sulphuric acid becomes turbid and deposits small mammellated crystals, or a resinous mass, which gradually changes into crystals of the acid salt, $C^{20}H^{21}NO^4.SH^2O^4$, which may be purified by recrystallisation from alcohol.

Tartrate of Hydroberberine forms mammellated groups of needles.

Ethyl-hydroberberine. $C^{22}H^{25}NO^4 = C^{20}H^{20}(C^2H^5)NO^4$.—Hydroberberine heated for some hours in a water-bath with an excess of iodide of ethyl, yields a pasty mass, which when taken up by alcohol, forms tufts of yellow rhomboïdal prisms, consisting of hydriodate of ethyl-hydroberberine, $C^{22}H^{26}NO^4.HI$, very soluble in water, and containing water of crystallisation, which they give off entirely at 100°. The mother-liquors of the preparation still yield small quadrangular laminæ of another substance, the admixture of which with the first crystals must be avoided.

HYDROBORACITE. *Hydrated Borate of Calcium* and *Magnesium.* $\left.\begin{matrix}3CaO\\ 3MgO\end{matrix}\right\}8B^2O^3.18H^2O$.—Resembles fibrous and foliated gypsum. Colour white with spots of red, from iron. Translucent in thin plates. Melts before the blowpipe to a clear glass, tinging the flame slightly green and not becoming opaque. Heated in a tube it yields water. It is slightly soluble in water, the liquid having a faint alkaline reaction. It dissolves readily in nitric and hydrochloric acids. It was found by Hess (Pogg. Ann. xxxi. 49) in a collection of Caucasian minerals.

HYDROBOROCALCITE. Syn. with BOROCALCITE.

HYDROBROMIC ACID. See BROMIDE OF HYDROGEN (i. 672).

HYDROBRYOTIN. $C^{42}H^{74}O^{16}$.—An amorphous substance, insoluble in ether, but soluble in alcohol, produced by the decomposition of bryonin (i. 685).

HYDROBUCHOLZITE. See KYANITE (p. 449).

HYDROCALCITE. Hydrated carbonate of calcium, $CaCO^3.5H^2O$. Found in small rhombohedral crystals, forming an incrustation on wood under water. (See CARBONATES.)

HYDROCARBONS. Compounds consisting of carbon and hydrogen only. The number of bodies of this class at present known is very great, but the most important of them may be arranged in the following groups:

1. Alcohol-radicles	. . $(C^nH^{2n+1})^2$	homologous with	Methyl $(CH^3)^2$
2. Hydrides of alcohol-radicles	. . C^nH^{2n+2}	,,	Marsh-gas (CH^4)
3. Olefines	. . C^nH^{2n}	,,	Ethylene or Olefiant gas (C^2H^4)
4. Hydrocarbons	. . C^nH^{2n-2}	,,	Acetylene (C^2H^2)
5. Camphenes or Terebenes	C^nH^{2n-4}	isomeric with	Turpentine, $C^{10}H^{16}$
6. Hydrocarbons	. . C^nH^{2n-6}	homologous with	Benzene (C^6H^6)
7. Hydrocarbons	. . C^nH^{2n-12}	,,	Naphthalene, $C^{10}H^8$

The most fruitful source of hydrocarbons is the dry or destructive distillation of organic bodies, the nature of the products varying according to the temperature at which

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us, coal when distilled at a bright red, as for the hydrocarbons belonging to the second, third, fourth r with a considerable quantity of naphthalene; but ure at which complete decomposition can take place ng chiefly to the second and third groups, together ch probably also belongs to the second group. The s buried beneath the surface of the earth has also ons belonging to the second group, as shown by the nd in certain parts of North America, which, as lmost wholly of alcoholic hydrides of the general

ed by the dehydration of alcohols of the series ohols with strong sulphuric acid or chloride of corresponding olefine, according to the equation

e case of some of the higher alcohols, is much more imply, resulting in the formation, not only of the composed, but likewise of several of its homologues, drides; thus Wurtz, by distilling amylic alcohol ot only amylene, C^5H^{10}, but likewise all its homo- $C^{10}H^{20}$, together with the corresponding alcoholic

ies, viz. methylene, CH^2, is not known in the free opylene, C^3H^6, and tetrylene, C^4H^8, are gaseous at ^{10}, and its higher homologues up to decatylene, d at ordinary temperatures, their boiling points crease. Cerotene, $C^{27}H^{54}$, and melissene, $C^{30}H^{60}$ t 57° or 58°, the latter at 62°.

rkable for the facility with which they unite with g compounds homologous with, or analogous to, affords an easy mode of separating these olefines ey may be present: for on passing the gaseous romine, the olefines are absorbed and converted ame), while the other hydrocarbons in the mix-

h *sulphuric anhydride;* and this property like- ng them from gaseous mixtures: thus, if a ball of dhausen sulphuric acid be passed up into a mix- hydrogen, carbonic oxide, &c., the ethylene will ll remain behind.

ily with strong *sulphuric acid*, forming compound $\left.\begin{matrix} (SO^2)'' \\ C^{2n+1} \\ H \end{matrix}\right\} O^2$, homologous with ethyl-sulphuric or sul-

ecial importance, since it enables us to pass from l: thus ethylene-gas shaken up with strong sul- d, $\left.\begin{matrix} SO^2 \\ C^2H^5.H \end{matrix}\right\} O^2$, whence, by distillation with water,

ydrochloric acid, hydrobromic acid, &c. Wurtz 14) that amylene combines with hydrobromic and omeric with iodide and bromide of amyl; and by th moist oxide of silver, he has obtained a hydrate amylic alcohol. All these compounds are dis- with which they are isomeric, by the facility with er the influence of various reagents. Thus hydrate ic acid gas, and is resolved into hydriodate of d; similarly with hydrochloric acid. Bromine de of amylene and water; chlorine similarly but the compound $C^5H^{10}.NaHO$, which when treated ields amylene, hydrate of amylene, and iodide of

$$HI = C^5H^{10} + C^5H^{10}.H^2O + NaI.$$

decomposed by sodium, yielding iodide of sodium, lcoholic potash, it yields amylene and iodide of ucts are iodide of ammonium, amylene, and a erhaps identical with amylamine.

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The amylene in all these compounds appears to be but loosely united with the w or the acid, and is set at liberty on the slightest disturbance; whereas in their ison the amyl-compounds, the group C^5H^{11}, which is not capable of existing in the sepa state, is easily transferred from one compound to another, and it is only with consi able difficulty that two molecules of it can be made to coalesce into one so as to f free amyl, $C^{10}H^{22}$.

Hexylene, C^6H^{12}, also unites with hydriodic acid, and the hydriodate, treated w water and oxide of silver, yields a hydrate, $C^6H^{12}.H^2O$, isomeric with hexylic alcohol, possibly identical with the β hexylic alcohol discovered by Wanklyn and Erlenmey

The formation and properties of the alcohol-radicles (i. 96) and their hydri (iii. 180) have already been considered. Recent investigations seem to show that th is no essential difference between the alcohol-radicles in the free state, and th hydrides (pp. 144, 182).

Of the hydrocarbons, C^nH^{2n-2}, homologous with acetylene, only three have b obtained, viz. acetylene, C^2H^2 (i. 1111), allylene, C^3H^4 (i. 1112), and croton lene, C^4H^6 (ii. 965).

Of the hydrocarbons, C^nH^{2n-6}, homologous with benzene, five are known, viz. benze C^6H^6 (i. 541), benzylene or toluene, C^7H^8 (i. 577), xylene, C^8H^{10}, cumene, C^9 (ii. 173), and cymene, $C^{10}H^{14}$ (ii. 296). They have all been specially considered, exce ing xylene, which will be described in its place. These hydrocarbons, as already observ are produced by the destructive distillation of coal and other organic substances at h temperatures; also in a great variety of chemical reactions (see Benzene). They distinguished by the facility with which they form substitution-compounds with conc trated nitric acid, *e.g.* nitrobenzene, $C^6H^5(NO^2)$. These nitro-compounds, being hea oily liquids of rather high boiling point, afford the means of separating these hyd carbons from others, such as the alcoholic hydrides, with which they may be mix (p. 146). The same compounds subjected to the action of reducing agents, such sulphydric acid or ferrous acetate, yield organic bases, which may be supposed to derived from the nitro-compound by substitution of amidogen, NH^2, for nitryl, N *e.g.* aniline, $C^6H^5(H^2N)$, from nitrobenzene.

The camphenes, or terebenes, $C^{10}H^{16}$, isomeric with oil of turpentine, exist rea formed in a great number of plants. For their general properties see vol. i. p. 724

The hydrocarbons are the simplest of all organic compounds, and may be regard as the starting-points from which all others may be derived, by substitution or ad tion (see Nucleus-theory and Radicles). Hence, of late years, the attention chemists has been very much directed to the discovery of methods for producing th compounds directly from their inorganic elements; since, when this is accomplish the formation of a great number of the more complex organic compounds, by t synthesis of their elements, becomes a comparatively easy matter. The most su cessful efforts in this direction have been made by Berthelot (Chem. Soc. J. xvii. 3 who has succeeded in producing certain hydrocarbons by direct combination of t elements carbon and hydrogen, and from these producing others of great complexity

1. Acetylene, C^2H^2, is produced when hydrogen is passed over carbon heated bright redness by the electric arc. This gas, passed into a solution of cuprous chlori forms cuprous acetylene, $C^2(Cu^2)''H^2$; and this compound, subjected to the acti of nascent hydrogen (evolved by the action of zinc on ammonia), yields ethylene

$$\underset{\text{Acetylene.}}{C^2H^2} + H^2 = \underset{\text{Ethylene.}}{C^2H^4}$$

Ethylene thus obtained may be converted into alcohol, and from this a host of oth compounds, ethers, acetones, acids, amines, &c. may be derived.

2. Hydrocarbons may be formed from inorganic compounds containing their e ments, such as water and sulphide of carbon, or carbonic anhydride. A mixture sulphydric acid and sulphide of carbon, subjected to the action of copper at a re heat, yields marsh-gas:

$$CS^2 + 2H^2S + 4Cu = CH^4 + 4CuS.$$

Marsh-gas may also be formed from carbonic anhydride, though by a less direct pr cess, viz. by first converting the latter compound into carbonic oxide, this into form acid ($CO + H^2O = CH^2O^2$, ii. 683), then subjecting a salt of this acid, the barium salt, for example, to dry distillation:

$$2C^2H^2BaO^4 = CH^4 + CO^2 + 2BaCO^3.$$

Marsh-gas, mixed with an equal volume of chlorine, yields chloride of methyl, CH^3 and this ether distilled with potash, yields methylic alcohol, CH^4O, which is form by the addition of 1 at. oxygen to marsh-gas, whereas ethylic alcohol is formed fr ethylene by the addition of the elements of water. These two modes of formation

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alcohols from hydrocarbons are general, the former applying to all homologues of marsh-gas, the latter to all homologues of ethylene.

3. A hydrocarbon may be transformed into another of greater complexity: *a*. By *direct condensation*. Marsh-gas raised to a very high temperature, or subjected to the action of a series of induction-sparks, is converted into acetylene, which contains twice the quantity of carbon in the same volume: $2CH^4 = C^2H^2 + H^4$. The condensation of marsh gas may, however, be carried considerably further, and made to yield naphthalene, a hydrocarbon containing ten times as much carbon in the same volume: $10CH^4 = C^{10}H^8 + H^{32}$ viz. by enclosing the marsh-gas in a tube of very refractory glass, and keeping it for several hours at a temperature as near as possible to that at which Bohemian glass softens. The condensation may also be effected by subjecting the vapour of bromoform, $CHBr^3$ (tribrominated methylic hydride), to the action of copper at a red heat, so as to remove the bromine. The residue, CH, then suffers a six-fold condensation, yielding benzene, C^6H^6.

b. By the union of two simple molecules into a more complex molecule. Thus, when a mixture of marsh-gas and carbonic oxide is slowly passed through a tube heated to low redness, tritylene, C^3H^4, is produced:

$$2CH^4 + CO = C^3H^4 + H^2O.$$

This reaction may perhaps explain the formation of a small quantity of tritylene in the distillation of formate of barium; and it is doubtless to reactions of the same order that we may attribute the production of hydrocarbons of the same series, which has been experimentally demonstrated as high as amylene, in the distillation of acetates.

There are also other ways in which complex hydrocarbons may be built up by the union of those of more simple constitution. Wurtz has shown (Ann. Ch. Pharm. cxxiii. 202; cxxvii. 55), that amylene, C^5H^{10}, may be produced by the union of the alcohol-radicles ethyl and allyl:

$$C^2H^5 + C^3H^5 = C^5H^{10},$$

this combination being brought about by the mutual action of zinc-ethyl and iodide of allyl. A number of other hydrocarbons are, however, formed at the same time, the following having been isolated and analysed:

C^2H^4	C^3H^6	C^5H^{10}	C^5H^{12}	C^6H^{10}	$C^{10}H^{20}$
Ethylene.	Tritylene.	Amylene.	Hydride of amyl.	Allyl.	Decatylene.

The ethylene and tritylene are produced by the mutual action of the ethyl and allyl groups:

$$C^2H^5 + C^3H^5 = C^2H^4 + C^3H^6.$$

Decatylene, $C^{10}H^{20}$, results from the condensation of two molecules of amylene into one. Besides these compounds, there are also formed other hydrocarbons, boiling above 200° (decatylene, the least volatile of those above-mentioned, boils at 160°), and containing, like allyl, a smaller proportion of hydrogen than the olefines. The formation of these hydrocarbons explains that of hydride of amyl, in which the proportion of hydrogen is larger than in the olefines.

The hydrocarbon, C^5H^{10}, obtained in the reaction just described, possesses the principal physical and chemical properties of amylene produced from amylic alcohol by the action of chloride of zinc, and, therefore, is not merely an isomer (ethyl-allyl) of that compound. This formation of amylene from two hydrocarbons of lower molecular weight is analogous to that of chloride of heptyl, $C^7H^{15}Cl$, by the action of chlorine on ethyl-amyl, $C^2H^5.C^5H^{11}$, and of chloride of decatyl, $C^{10}H^{21}Cl$, by that of chlorine on amyl itself, observed by Schorlemmer.

HYDROCARBOXYLIC ACIDS. (Lerch, Ann. Ch. Pharm. cxxiv. 20; Rép. Chim. pure, 1863, p. 143; Jahresb. 1862, p. 276.)—This name is applied to three acids produced, together with others, by the decomposition of carboxide of potassium, the black amorphous substance formed in the preparation of potassium in the ordinary way, and likewise by the direct combination of potassium with carbonic oxide. This substance remains unaltered when kept in rock-oil or in a dry vacuum, but when exposed to the air, it absorbs moisture rapidly, acquiring a cherry-red and finally a yellow colour: it absorbs oxygen only when moist. When treated with water, alcohol or ether, out of contact with the air, it gives off gas, and leaves a black glutinous substance, which turns red on exposure to the air, and dissolves in water with red colour and without disengagement of gas. This mass yields, besides oxalic acid, three series of acids, including croconic acid (ii. 109).

Perfectly unaltered carboxide of potassium, to which Brodie assigns the formula C^6K^2, yields, when treated with hydrochloric acid, an acid crystallising in white needles and having the composition $C^{10}H^{10}O^{10}$; this is trihydrocarboxylic acid.

If the carboxide of potassium be first treated with alcohol and then with hydrochloric acid, it yields black needles of dihydrocarboxylic acid, $C^5H^4O^5$ or $C^{10}H^8O^{10}$.

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If the air has had access to the mass before or after the treatment with afterwards yields, with hydrochloric acid, dark garnet-red crystals of h boxylic acid, $C^{10}H^6O^{10}$.

Lastly, if the mass has been left in contact with the air till it has turned qui it is then treated with hydrochloric acid, a fourth acid is obtained, called ca acid, the potassium-salts of which are composed according to the formulæ and $C^{10}K^4O^{10}$. On attempting to isolate this acid, fine colourless prisms of rh acid, $C^5H^4O^6$, are obtained, being derived from the preceding by fixation of splitting up of the molecule:

$$C^{10}H^4O^{10} + 2H^2O = 2C^5H^4O^6.$$

In addition to these acids, croconic acid, $C^5H^2O^5$ (formed from carboxyl division of the molecule), and oxalic acid, are obtained as final products of tion.

The formation of dihydrocarboxylic, hydrocarboxylic, and carboxylic acids tion of trihydrocarboxylic acid is represented by the following equations:

$$C^{10}H^8O^{10} + O = C^{10}H^8O^{10} + H^2O.$$
$$C^{10}H^6O^{10} + O = C^{10}H^6O^{10} + H^2O.$$
$$C^{10}H^6O^{10} + O = C^{10}H^4O^{10} + H^2O.$$

Trihydrocarboxylic acid. $C^{10}H^{10}O^{10} = \left.\begin{matrix} C^{10}H^6O^6 \\ H^4 \end{matrix}\right\} O^4$.—This acid is pr already observed, by the action of hydrochloric acid on carboxide of potassi has not been exposed to the air; also by the reduction of dihydrocarboxylic forms white silky needles which, when exposed to moist air, quickly turn re ultimately converted into dihydrocarboxylic acid. Its solution is acid, colou very sensitive to the action of oxidising agents. By nitrate of potassium, it is into oxycarboxylic acid, with evolution of nitrogen. Of the 10 at. hydrogen in its molecule, 6 at. are easily removed by oxidation, giving rise to new rad those of dihydrocarboxylic, hydrocarboxylic and carboxylic acids, whereas the 4 at. are basic, and easily replaceable by metals, but not removable by oxida the potassium-salt also, $C^{10}K^4O^{10}$, 6 at. K may be removed, two at a time, by whereas the remaining 4 at. K appear to be irremovable: hence the rationa of the acid above given. In like manner, dihydrocarboxylic acid contains hydrocarboxylic acid, 2 at. H, removable by oxidation.

The trihydrocarboxylates of the alkali-metals are soluble in water, the o are sparingly soluble or insoluble: they all become coloured by exposure t yielding salts of the following acids:

Dihydrocarboxylic acid. $C^{10}H^8O^{10} = \left.\begin{matrix} C^{10}H^4O^6 \\ H^4 \end{matrix}\right\} O^4$.—This acid for metallic-shining monoclinic crystals, grouped in very thin tufts; the thinne have a wood-yellow colour, and exhibit trichroïsm. They are permanent i even at 100°, dissolve readily in water and alcohol, slowly in ether; the sol red by transmitted, violet by reflected light.

The salts of this acid are as unstable as those of the preceding. Those of t metals are black, soluble in water and crystallisable; the rest are blue or red pre they are very easily converted by oxidation into rhodizonates or carboxylates

Hydrocarboxylic acid, $C^{10}H^6O^{10} = \left.\begin{matrix} C^{10}H^2O^6 \\ H^4 \end{matrix}\right\} O^4$, was obtained accide the preparation of the preceding acid from a black mass which had undergo alteration. It crystallises from alcohol in long brown needles, which in con water are immediately resolved into dihydrocarboxylic and rhodizonic acids:

$$2C^{10}H^6O^{10} + 2H^2O = C^{10}H^8O^{10} + 2C^5H^4O^6.$$

HYDROCAROTIN. $C^{18}H^{30}O$. (Husemann, Ann. Ch. Pharm. cx Jahresber. 1861, p. 754).—A substance contained, together with carotin (i. 8 root of the carrot (*Daucus carota*). To obtain these substances, the crushe are pressed, the residue is repeatedly washed out with water, and the united sol mixed with a little dilute sulphuric acid and tincture of galls (which facil separation of the coagulum); the glutinous precipitate, freed by pressure fro closed liquid, is boiled six or seven times in the half-dry state with 5 o alcohol of 80 per cent.; and the residue is treated with sulphide of carbon to e carotin. The alcoholic extract contains hydrocarotin together with manni carrots are a year old, but not if they are fresh), sugar, a fixed oil, and a small carotin.

Hydrocarotin crystallises from the alcoholic extract, after long standing, i crystals, which may be freed from mannite (if present) by recrystallisa

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hot alcohol, and finally by boiling with water. It is tasteless and inodorous, crystallises in large colourless silky laminæ, from ether in flat rhombic prisms; is lighter than water (which does not wet it); melts at 126·8°; dissolves in alcohol, and more easily in ether, sulphide of carbon, benzene, volatile oils, and chloroform. When heated above 100°, it turns yellow to yellowish red; after fusion it remains amorphous, and then dissolves less easily in benzene and sulphide of carbon.

Hydrocarotin is not precipitated from its alcoholic solution by metallic salts or tannic acid; it is not altered by the action of caustic alkalis, strong acids, or oxidising agents: with *fuming nitric acid*, it appears to form a nitro-compound. Strong *sulphuric acid* colours it red and dissolves it completely at a gentle heat, forming a solution from which it is precipitated by water apparently unaltered, but in the amorphous state. With *chlorine* it forms a resinous substitution-product, $C^{18}H^{26}Cl^4O$; with *bromine* a similar body, $C^{18}H^{27}Br^3O$, whose ethereal solution, when treated with alcoholic potash, gives up bromine, and forms a yellowish-red substance soluble with blood-red colour in sulphide of carbon. *Iodine* also, in sunshine, appears to form a substitution-product with hydrocarotin.

HYDROCERITE. See LANTHANITE.

HYDROCHINONE. See HYDROQUINONE.

HYDROCHLORE. See PYROCHLORE.

HYDROCHLORIC ACID. See CHLORHYDRIC ACID (i. 890).

HYDROCHRYSAMIDE. $C^7H^6N^2O^2$. (Schunck, Ann. Ch. Pharm. lxv. 231.)—A compound produced by the action of reducing agents on chrysammic acid (i. 955). It may be prepared by adding chrysammic acid to a boiling solution of sulphide of potassium containing excess of caustic potash; or to a boiling solution of protochloride of tin, afterwards removing the excess of acid, dissolving the residue in boiling potash, and leaving the solution to crystallise. It is difficult, however, by the latter method to obtain it free from oxide of tin.

Hydrochrysamide forms needle-shaped crystals, of a fine blue colour by transmitted, and metallic red by reflected light. Heated in a small tube, it gives off violet vapours, which condense in crystals on the cold parts of the tube; the greater part, however, is decomposed, giving off ammonia and leaving charcoal. It is insoluble in boiling *water*, and sparingly soluble in boiling *alcohol*, to which it imparts a faint blue tint. It is dissolved by strong *sulphuric acid*, and reprecipitated in blue flakes by water.—It is decomposed by boiling *nitric acid*, and by *chlorine* in presence of water. It dissolves in *potash* and in *alkaline carbonates*, forming solutions of the colour of sulphindigotic acid; acids precipitate it therefrom in blue flakes.

HYDROCINNAMIDE. $C^{27}H^{24}N^2 = N^2(C^9H^8)^3$. *Cinnhydramide. Hydride of Asocinnamyl.* (Laurent, Rev. scient. x. 119.)—Produced by the action of ammonia on hydride of cinnamyl:

$$3C^9H^{10}O + 2NH^3 = N^2(C^9H^8)^3 + 3H^2O.$$

When purified by recrystallisation from hot alcohol and ether, it forms colourless right prisms with rectangular base, but having their bases replaced by two triangular facets, meeting at a very obtuse angle. It is inodorous, insoluble in water, fusible, and solidifies on cooling to a transparent amorphous mass like gum. It is decomposed by distillation, yielding an oil and a solid substance. It is not decomposed by boiling hydrochloric acid, or by alcoholic potash; but boiling nitric acid decomposes it, yielding a product which melts in boiling water.

Dumas and Peligot, by treating oil of cinnamon with dry ammonia gas, obtained a product which crystallised from alcohol and ether in silky tufts, and to which they assigned the formula $C^9H^{10}O.NH^3$, but it probably consisted mainly of hydrocinnamide. (*Gerhardt's Traité*, iii. 385.)

HYDROCOTYLE ASIATICA. A plant used in India as a remedy against various cutaneous diseases. According to Lepire (J. Pharm. [3] xxviii. 47), it contains a peculiar principle, *vellarin* (from the Tamul name of the plant, *vallâraï*), which he describes as a bitter, strong-smelling oil, soluble in weak alcohol and in ether, thickening on exposure to the air, soluble in aqueous ammonia, insoluble in potash.

HYDROCROCONIC ACID. $C^5H^4O^5 = \left.\begin{matrix}C^5H^2O^3\\H^2\end{matrix}\right\}O^2$. (Lerch, Ann. Ch. Pharm. cxxiv. 20.)—An acid produced by the action of hydriodic acid on croconate of potassium in closed vessels. On mixing the product of the reaction with alcoholic potash-solution, hydrocroconate of potassium, $C^5H^1K^2O^5$, separates as a dingy red precipitate, which crystallises from hot water in crimson needles. The blood-red solution of this

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salt is converted into croconate (and a small quantity of oxalate) of potassiu exposure to the air, especially in presence of alkali.

Hydrocroconic acid is soluble in water, alcohol, and ether, and does not cryst The *barium-salt*, $C^5H^2Ba''O^5$, is a pæony-red precipitate, soluble in hydroc insoluble in acetic acid. The *lead-salt*, $C^5H^2Pb''O^5$, is also a red precipitate.

HYDROCYANHARMALINE. See HARMALINE (p. 8).

HYDROCYANIC ACID. See CYANIDE OF HYDROGEN (ii. 214).

HYDRODOLOMITE. A hydromagnesite, having part of the magnesium re by calcium. Occurs on Somma in isolated, sinter-like, globular or stalactitic, masses, having a white or yellowish white colour. According to Kobell (J. pr. xxxvi. 304), it contains 25·22 per cent. lime, 24·28 magnesia, 33·10 carbonic anhy and 17·40 water: whence the formula $3[(Mg; Ca)''CO^3.H^2O] + Mg''H^2O^2$. (K melsberg.)

HYDRO-ELECTRIC MACHINE. See ELECTRICITY (ii. 408).

HYDROFERRICYANIC ACID. See FERRICYANIDES (ii. 244).

HYDROFERROCYANIC ACID. See FERROCYANIDES (ii. 226).

HYDROFLUOBORATES. See BORON, FLUORIDE OF (i. 632).

HYDROFLUOSILICATES. See SILICON, FLUORIDE OF.

HYDROGALACTOMETER. An arrangement described by Zen (Jahrb. pr. Pharm. xx. 65; Jahresb. 1850, p. 619) for determining the amou water added to normal milk. The milk is coagulated by a few drops of hydroc acid, and the volume of the curd, separated by filtration through flannel, is com with that obtained in a similar manner from pure milk.

HYDROGEN. *Atomic weight* = 1. *Symbol* H. (*Inflammable air*, *Wasse Hydrogenium.*)—The older alchemists do not appear to have been acquainted wit gas. The evolution of an air during the solution of iron in sulphuric acid wa noticed in the sixteenth century by Paracelsus. The inflammability of the ai produced, was observed in the seventeenth century by Turquet de Mayern afterwards (1672) by Boyle, in his "New Experiments touching the relation be Flame and Air." Lemery in 1700 observed the detonating property of this in mable gas. But the first exact experiments on its nature were made in 17 Cavendish, who showed that it is a peculiar kind of air, which he called *inflam air;* that it is produced when iron, zinc, or tin is dissolved in dilute sulphu hydrochloric acid; and that different metals evolve different quantities of the gas also estimated its specific gravity at $\frac{1}{11}$ of that of common air. (It is really about

The inflammable air generated in these processes was, however, for some time founded with other kinds of inflammable air, such as those produced by the destru distillation of organic bodies, by the imperfect combustion of charcoal—with vap ether, &c., all of which were supposed to consist essentially of the same inflam principle modified by the admixture of other substances. Moreover, it was sup that the inflammable principle developed in the solution of metals in acids, proc from the metal, and that it was either phlogiston or intimately related thereto.

The production of moisture in the burning of hydrogen, appears to have bee noticed by Macquer and De la Metherie, in 1766; but no one at that time posed that the only product of the combustion was water. Lavoisier supposed hydrogen, like other combustible bodies, produced an acid in burning, and made se unsuccessful experiments to obtain this acid. But the grand discovery that wa the sole product of the combustion of hydrogen was made by Cavendish, in and published in 1783. Cavendish showed that 423 volumes of hydrogen requir combustion 1,000 volumes of air (which contain 210 volumes of oxygen, and will, t fore, burn exactly 420 volumes of hydrogen); and, moreover, that when hydroge oxygen gases are burnt together in certain proportions, nearly all the gas disap nothing but slight impurities remaining behind. These results were afterwards confirmed by the experiments of Lavoisier and Laplace (see GAS, ii. 780).

Sources.—Hydrogen is never found in the free state. The compound which co it in the greatest abundance is marsh-gas, of which it forms one-fourth. Of wa forms one-ninth. It occurs in smaller quantities in combination with phosph sulphur, iodine, bromine, carbon and nitrogen, and is an essential constituent of n all organic compounds.

Preparation.—Hydrogen is generally obtained by the decomposition of water, dilute acids.—1. It is produced in the state of greatest purity by electrolysis, as al explained in the article ANALYSIS OF GASES (i. 285).

2. By passing vapour of water over iron nails or wire contained in a gun-barrel horizontally in a furnace, and heated to bright redness. The iron is thereby conv

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into ferroso-ferric oxide, Fe^3O^4, while hydrogen gas passes over, and may be collected over water.

3. By introducing potassium or sodium into an inverted tube or cylinder filled with water or alcohol, and standing in a vessel of the same liquid. It is best to wrap the metal in a piece of paper before plunging it under the mouth of the cylinder:

$$\underset{}{H^2O} + Na = \underset{\text{Hydrate of sodium.}}{NaHO} + H.$$

$$\underset{\text{Alcohol.}}{C^2H^6O} + Na = \underset{\text{Ethylate of sodium.}}{C^2H^5NaO} + H.$$

4. By dissolving zinc or iron in sulphuric acid diluted with an eight-fold quantity of water, or in hydrochloric acid diluted with twice its weight of water:

$$H^2SO^4 + Zn = ZnSO^4 + H^2,$$

and

$$2HCl + Zn = ZnCl^2 + H^2.$$

This is the most convenient method of obtaining the gas for general purposes.—5. By dissolving zinc, in contact with iron or platinum, in solution of caustic potash, zincate of potassium being then formed:

$$\underset{\text{Hydrate of potassium.}}{2KHO} + Zn = \underset{\text{Zincate of potassium.}}{ZnK^2O^2} + H^2.$$

The use of the iron is to form an electric couple with the zinc, the latter then acting on the positive or active metal.

6. By acting on cuprous hydride with hydrochloric acid:

$$Cu^2H^2 + 2HCl = Cu^2Cl^2 + 2H^2.$$

7. By heating formates or oxalates with excess of hydrate of potassium, sodium, or calcium:

$$\underset{\text{Formate of potassium.}}{CHKO^2} + KHO = \underset{\text{Carbonate of potassium.}}{CK^2O^3} + H^2.$$

$$\underset{\text{Oxalate of potassium.}}{C^2K^2O^4} + 2KHO = 2CK^2O^3 + H^2.$$

8. By the action of hydrate of potassium on certain organic bodies having a tendency to form acids by oxidation:

$$\underset{\text{Hydride of benzoyl.}}{C^7H^6O} + KHO = \underset{\text{Benzoate of potassium.}}{C^7H^5KO^2} + H^2.$$

Purification.—Hydrogen prepared by dissolving zinc or iron in sulphuric acid—which is the method most used—may contain the following impurities:—1. *Sulphurous acid*, if this acid is present in the sulphuric acid used.—2. *Nitrous oxide* or *nitric oxide gas*, if the sulphuric acid contains nitric oxide, nitrous acid, or nitric acid.—3. *Sulphydric acid*, if the zinc contains sulphide of zinc, or if the sulphuric acid contains sulphurous acid—or if a fresh quantity of strong sulphuric acid be added to the dilute acid already acting on the zinc, without mixing it well with the liquid.—4. *Phosphoretted hydrogen*, if the zinc contains phosphorus.—5. *Arsenetted hydrogen*, if the zinc contains arsenic, or if the sulphuric acid contains arsenious acid.—6. *Carbonic anhydride* has occasionally been observed in hydrogen prepared with peculiar kinds of zinc. These impurities, which give the gas an unpleasant odour, may be removed by passing it over substances which absorb or decompose the adventitious gases. Dumas passed the gas through two U-tubes, each about three feet long, and filled with broken glass, the glass in the first tube being moistened with nitrate of lead, which removes the sulphydric acid, and that in the second with sulphate of silver, by which the arsenetted hydrogen is separated; then through a third U-tube filled with fragments of pumice-stone saturated with strong potash; and, lastly, to render it anhydrous, first through a tube containing fragments of hydrate of potassium, then through another containing phosphoric anhydride or pumice-stone soaked in oil of vitriol. To avoid the presence of oxides of nitrogen, it is best to use sulphuric acid perfectly free from those oxides.

Hydrogen gas obtained by the use of iron may contain the same impurities as that prepared with zinc—and in addition:—1. *Ferruretted hydrogen*—to be removed by fuming nitric acid or solution of mercuric chloride; and 2. The vapour of an oily hydrocarbon, which is produced in larger quantity as the iron contains more carbon, and communicates a peculiarly repulsive odour to the gas. It may be removed by passing the gas through alcohol, and the alcohol may be afterwards separated by water.

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cording to Döbereiner (Schw. J. iii. 377), the gas obtained with either zinc or iron
ıy be deprived of all odour by 24 hours' contact with moistened charcoal powder.
In whatever manner the gas may be prepared, it generally contains a small quantity
atmospheric air, proceeding from the liquids used in the preparation. The nitrogen
nnot be removed; but the oxygen may be separated by leaving the gas for a while
contact with spongy platinum, which causes the oxygen to unite with a portion of
hydrogen and form water.

Properties.—Hydrogen is a colourless gas, of specific gravity 0·0693. It is the
htest of all known substances, being about 14½ times as light as atmospheric air; it
ıy therefore be used for inflating balloons. Soap-bubbles filled with it rise rapidly
the air. It escapes rapidly out of vessels with their mouths turned upwards; but a
de-mouthed vessel filled with it may be carried with its mouth downwards for a
ısiderable distance without the gas escaping. For the same reason, it is easily
llected by displacement, without the use of water, viz. by holding the vessel which
to receive it, over the extremity of a vertical tube attached to the mouth of the
ıerating vessel.

Hydrogen is odourless when quite pure, but as usually prepared, it has a disagreeable
our, arising from impurities. Small animals introduced into the gas die instantly.
man, the pure gas excites, after two inspirations, disagreeable sensations and loss
muscular power; when mixed with air, it may be breathed for a longer time, but
parts a peculiar squeaking tone to the voice. It is not directly injurious, but so long as
s inhaled, oxygen gas, which is essential to life, is prevented from entering the lungs.
Hydrogen is very inflammable, and burns in the air with a pale blue flame. It does
support the combustion of those bodies which burn in the air: for instance, if a jar
l of hydrogen be held with its mouth downwards, and a lighted taper plunged into
the hydrogen will be set on fire at the mouth, but the taper will be extinguished.
jet of oxygen will, however, burn in hydrogen, as well as a jet of hydrogen in oxygen,
ough with a somewhat different appearance. The experiment may be made by
ting fire to hydrogen-gas at the mouth of a bottle, and then directing a jet of oxygen
ough the flame into the body of the gas. A flame will then be formed at the orifice
the jet, and will continue to burn till the hydrogen is exhausted.

Hydrogen and *oxygen* unite to form water, in the proportion of 2 volumes of hydrogen
l volume of oxygen; and when the gases are mixed in these proportions, they may
made to unite, either slowly or rapidly, the entire volume of gas disappearing. On
nging a burning body in contact with the mixture, or passing an electric spark
ough it, combination instantly takes place throughout the whole mass, attended
h great and sudden rise of temperature, whereby the mixed gases, or rather the
tery vapour resulting from their union, are expended with a force sufficient to shatter
containing vessel, if not of great strength. If the vessel is entirely closed, and
ng enough to resist the expansive force of the gas, no noise is heard; but if the
uth of the vessel be left open, or the gas be able to force for itself a passage into the
a loud detonation is the result, arising from the concussion of the air by the
aping gases. The same effect is produced, though with much less intensity, when a
xture of 2 vol. hydrogen and 5 vol. atmospheric air (containing 1 vol. oxygen, the
ntity required to unite with 2 vol. hydrogen) is exposed to the action of flame or
electric spark. Hence, in manipulating with hydrogen, great care must be taken
prevent accidental admixture of air, as, if such admixture takes place unknown to the
rator, explosions of dangerous character may ensue when the gas comes in contact with
ne. In collecting the gas, a considerable quantity should be suffered to escape before
of it is collected, so that the air in the apparatus may be completely eliminated.

The rapid combination of hydrogen and oxygen may be brought about, not only by
contact of flame, but also by the heat of a red-hot iron wire, or a coal hot enough to
ibit a visible glow by daylight. According to Biot (Gilb. Ann. xx. 99), the heat
duced by suddenly compressing the detonating gas, is sufficient to cause the explosion.
The presence of certain metals causes the gases to unite, even at ordinary tempera-
es. This effect is exhibited most strikingly by platinum, in the form of platinum-
nge or platinum-black (see PLATINUM); but it is also produced by a plate of the
tal rendered perfectly clean by rubbing it while hot with fused potash, then washing
vith water, dipping it into hot oil of vitriol, and again washing with water. Similar
cts are exhibited, though with less facility, by spongy iridium and osmium, finely
ided palladium, gold in the form of leaves or dust, and silver leaf. This peculiar
ion of platinum and other metals appears to be due (in part at least) to the absorp-
n of the gases by the metal, and their condensation within its pores. (See GASES, SORPTION OF, BY SOLIDS, ii. 804.)

The flame of hydrogen, though but feebly luminous, is intensely hot, and when a jet
oxygen is directed through it, as in the oxy-hydrogen blowpipe, the proportions of
two gases being properly adjusted so that neither of them is in excess, the heat

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obtained by chemical combination. (See Blow-

rgetically with *chlorine*, forming hydrochloric acid. mixed in the dark without uniting, but on expo- takes place gradually, and exposure to the direct lectric arc, or of lime ignited by the oxy-hydrogen tended with violent explosion. Explosion is also with a brick heated to 150° C. With *bromine*- dinary temperatures, even in sunshine; but partial th a red-hot wire. With *iodine*, it unites when a ur is passed through a red-hot tube, and, according at ordinary temperatures under the influence of nts hydrogen does not unite directly.

t of acids—properly so called—these bodies being ds, i. 39.) It also forms basic compounds, viz. ydrogen, &c.; and unites with metals and organic ydrides (p. 180).

E OF. See Antimony, Hydride of (i. 322).

OF. See Arsenic, Hydrides of (i. 371).

F. See Bromide of Hydrogen (i. 672).

F. See Chlorhydric acid (i. 890).

F. See Fluorhydric acid (ii. 669).

See Iodhydric acid.

Hydrogen forms two, or perhaps three, com- *de* or water, H^2O; the *dioxide* or *peroxide*, H^2O^2, to Baumert is a *trioxide* of hydrogen, H^2O^3.

of water will be described in a separate article; sition. We have already stated that when pure ed in the proportion of 2 vol. H to 1 vol. O, and disappears and nothing is produced but water. es as great as that of hydrogen: hence water is gen to 1 pt. of hydrogen. This composition has sented by the formula *HO*, water being thus and oxygen in equal numbers of atoms, and the eigh 8 times as much as that of hydrogen. But ing that a molecule of water contains 2 at. of gen—a composition represented by the formula

ready been given in the article Atomic Weights

ted. We will merely mention that, according to of oxygen and hydrogen are to one another as the the most simple supposition that can be made with the conclusions deduced from the dynamical

t and volume may be ascertained in various other of the component gases. When water is decom- olved very nearly in the proportion of 2 vol. H to always somewhat less than it should be on account The composition might also be ascertained by ot iron, measuring the volume of the hydrogen in weight of the iron.

adopted by Berzelius and Dulong (Ann. Ch. Ann. Ch. Phys. [3] viii. 189), which consists in btained as described at p. 193, over red-hot oxide s oxygen to the hydrogen, and forms water, which r attached to the end of the tube containing the aining dry chloride of calcium. The quantity of d the loss of weight which the oxide of copper s likewise determined. These experiments show proportion of 8 pts. by weight of oxygen to 1 pt.

	Dumas.	Berzelius and Dulong
1·11 . .	11·11 . .	11·1
8·89 . .	88·89 . .	88·9
0·00	100·00	100·0

(YDRATES (p. 179).

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Dioxide, or Peroxide of Hydrogen. HO or H^2O^2.—This remarkable compound was discovered by Thénard (*Traité de Chimie*, 4me. éd. iv. 2, 41).—It is produced when peroxide of potassium, sodium, barium, strontium, or calcium is digested in any acid which forms a soluble salt with the base resulting from the decomposition of the peroxide, the excess of oxygen not escaping as gas, but passing over to a portion of the water, and converting it into peroxide of hydrogen, *e.g.*:

$$BaO + HCl = 2BaCl + HO.$$

Preparation.—Pure baryta is prepared by igniting, in a porcelain retort, nitrate of barium free from iron and manganese. The baryta, broken into pieces about the size of a nut, is then put into a coated glass tube and heated to low redness, while a current of oxygen gas free from carbonic acid and dried by means of quicklime, is passed over it. For the first eight minutes the gas is eagerly absorbed by the baryta. After it has begun to escape from the farther end of the tube (to which a gas delivery-tube passing under water is fitted), the stream is still kept up for the space of ten or fifteen minutes. The peroxide of barium obtained by this process is, after cooling, preserved in a bottle. In the next place, 200 grms. of water are mixed with as much hydrochloric acid as will neutralise about 15 grms. of baryta. Into this liquid, contained in a cylinder, or better, in a dish of silver or platinum kept cool by surrounding it with ice, 12 grms. of peroxide of barium, slightly moistened and rubbed up in an agate mortar, are introduced by means of a wooden spatula: on agitating or stirring the liquid with the pestle, the whole dissolves completely and without effervescence. The baryta is next precipitated by sulphuric acid, added drop by drop till slightly in excess: the presence of an excess of the acid may be known by the sulphate of barium falling down more quickly than before. 12 grms. more of the peroxide are then dissolved in the same liquid, and likewise precipitated by sulphuric acid. The liquid, which now contains hydrochloric acid, sulphuric acid, a large quantity of water, and a small quantity of peroxide of hydrogen, is next separated by filtration from the sulphate of barium, the precipitate washed with a little water, and the last wash-water retained for future washings. The filtrate is again mixed, as above, twice with peroxide of barium, and twice with sulphuric acid. The filtration is then repeated, and the process continued in the same way, till 90 or 100 grms. of the peroxide are consumed. The liquid thus obtained would, on decomposition, yield from 25 to 30 measures of oxygen gas. To separate silica, alumina, sesquioxide of iron, sesquioxide of manganese, &c., which proceed from the porcelain retort in which the nitrate of baryta was ignited, the liquid is mixed with concentrated solution of phosphoric acid (2 or 3 pts. of phosphoric acid to 100 pts. of peroxide of barium)—then surrounded with ice, and supersaturated with pounded peroxide of barium: silica and the phosphates of iron, manganese, and aluminium then separate rapidly in flakes, and must be separated from the liquid by filtration through linen, and if necessary through paper. The presence of a large quantity of sulphate of barium renders the filtration difficult. (If no phosphoric acid were present, the sesquioxides of iron and manganese would fall down by themselves, and give rise to a rapid evolution of oxygen gas; but when they are mixed with phosphoric acid, they do not produce this effect.) Should the liquid still contain portions of these oxides, they must be separated by the addition of a slight excess of baryta-water; whereupon, the liquid must be immediately and rapidly filtered through several filters at once, and the filters squeezed between linen to get all out. The whole of the baryta must then be separated by carefully adding sulphuric acid in very slight excess, and filtering. The filtrate now contains nothing but water, peroxide of hydrogen, hydrochloric acid, and a very little sulphuric acid. To separate the hydrochloric acid, the liquid is surrounded with ice, and mixed with sulphate of silver. In the first place, sulphate of silver, obtained by heating nitrate of silver in contact with oil of vitriol in a platinum crucible, is introduced in the form of powder into the liquid—the whole being constantly stirred till the liquid becomes clear, a sign that the hydrochloric acid is wholly or nearly precipitated. Any hydrochloric acid that may still remain must be separated by cautiously adding more sulphate of silver. If the latter has been added in excess, it must be precipitated by carefully dropping in a dilute solution of chloride of barium. The liquid should contain neither hydrochloric acid nor silver, and should therefore give no precipitate either with solution of silver or with hydrochloric acid. The chloride of silver is separated by filtration and pressure, any portion of liquid which comes through turbid being filtered over again. To remove the sulphuric acid also, and obtain a pure mixture of water and peroxide of hydrogen, the liquid is placed in a glass mortar surrounded with ice, and rubbed up with slaked baryta previously pounded and diffused through water: the baryta is added till the sulphuric acid is very nearly saturated. The liquid is then filtered, the filter pressed between linen, and baryta-water added in slight excess. this often occasions the precipitation of oxide of iron and oxide of manganese, as well as sulphate of barium; hence the filtration

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must be rapidly performed. The excess of baryta is removed by cautiously adding dilute sulphuric acid, so that there may be rather a very slight excess of the acid than of the baryta. The whole of the sulphuric acid may likewise be removed by means of carbonate of barium obtained in a finely-divided state by precipitation, instead of by slaked baryta and baryta-water. Finally, to separate the whole or nearly the whole of the water, the vessel containing the liquid is placed in a dish containing oil of vitriol, and the whole placed under a receiver of the air-pump: the water then evaporates before the peroxide of hydrogen. The fluid is agitated from time to time. If it should deposit flakes of silica, which give rise to the escape of oxygen gas, it must be decanted off from them by means of a siphon: if it should evolve oxygen—which it will do as soon as it is so far concentrated as to contain about 250 times its volume of oxygen—two or three drops of sulphuric acid must be added to it. The concentration must be stopped after a few days, when the liquid is brought to such a state that when decomposed it would evolve 475 volumes of oxygen gas; for this residue, if left longer in vacuo, would evaporate as a whole. The peroxide of hydrogen must be kept in long glass tubes closed with stoppers and surrounded with ice; but, even under these circumstances, it decomposes slowly and evolves oxygen gas. (Thénard.)

2. Peroxide of barium is decomposed by hydrated hydrofluoric acid or solution of hydrofluosilicic acid, the whole being kept constantly cool: in this case, insoluble fluoride of barium or double fluoride of silicium and barium separates at once. As soon as sufficient quantities of acid and peroxide of barium have been mixed, the peroxide of hydrogen, still containing a large quantity of water, is filtered from the precipitate and concentrated in vacuo over oil of vitriol. (Pelouze, *Ber. Lehrb.* i. 411.)

Properties.—Colourless transparent liquid, of specific gravity 1·452; it does not freeze at −30°; evaporates in vacuo at ordinary temperatures without decomposition, though much less readily than water; does not redden litmus, but gradually bleaches both litmus and turmeric paper; has a harsh, bitter taste, similar to that of tartar-emetic; whitens the tongue and thickens the saliva; when placed upon the hand, it instantly turns the cuticle white, and after a time produces violent itching. (Thénard.)

Peroxide of hydrogen is miscible in all proportions with *water*, part of the water freezing out on exposure to cold. A solution containing eight times its own volume of oxygen gas begins to evolve gas at 50°, and subsequently gets into a state of violent ebullition, and when this has ceased, nothing is left but water. The peroxide likewise unites with *acids*, *e.g.* phosphoric, sulphuric, hydrochloric, nitric acid, &c., forming mixtures in which it is less easily decomposible than when alone.

It is doubtful whether peroxide of hydrogen has ever been obtained quite free from water. Thénard, however, found in a specimen prepared as above described, 6·02 per cent. hydrogen, and 93·98 oxygen, the formula HO requiring 5·88 H, and 94·12 O.

Decompositions.—The second atom of oxygen is retained by the hydrogen very loosely. Under various, and often enigmatical circumstances, it separates from the water in the form of gas, the volume of which at 14° and 0·76^{m}. bar. (29·8 inches) amounts to 475 times that of the liquid. The gas often escapes with such rapidity as to produce violent effervescence, and even explosion. Great heat is also developed, and when the experiment is made in the dark, even light is apparent.

The several modes of decomposition are as follows:—

1. In the circuit of the voltaic battery, peroxide of hydrogen, like water, is gradually resolved into hydrogen at the negative and oxygen at the positive pole—only that the proportion of oxygen is greater than in the decomposition of water. (Thénard.)

2. By a certain elevation of temperature. At freezing temperatures, peroxide of hydrogen is but very slowly decomposed; at ordinary temperatures, it merely evolves a bubble of oxygen now and then, the decomposition not being complete for months; at 20° the escape of gas becomes more perceptible. By suddenly raising the temperature to 100°, this gradual escape of gas may be converted into a kind of explosion. Finally, there remains behind nothing but pure water. Sunshine does not appear to accelerate the decomposition at ordinary temperatures. (Thénard.)

3. By contact with certain substances, which either remain unaltered, or take up part of the oxygen of the peroxide, or on the contrary themselves evolve oxygen.—The rapidity with which these substances induce the separation of oxygen from the peroxide depends partly on their chemical nature, partly on the minuteness of their mechanical division: the further this is carried, the more rapid is the action. (Thénard.)

a. Peroxide of hydrogen, whether pure or in aqueous solution, acts as a powerful oxidising agent. It converts arsenious acid into arsenic acid, sulphurous acid into sulphuric acid, sulphide of lead into sulphate of lead, and the hydrated protoxides of manganese, iron and cobalt, into the peroxide and sesquioxides respectively. The protoxides of barium, strontium, and calcium are transformed into the corresponding

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peroxides, which, being insoluble, are precipitated. The concentrated solution of p oxide of hydrogen acts with great violence upon certain of the elements, seleniu arsenic, molybdenum, chromium, &c., converting them at once into their highest oxid

b. Certain bodies, among which are included charcoal, many metals, and so metallic oxides, induce, by their mere contact, a more or less violent decomposition the peroxide into water and oxygen, without themselves undergoing any change: go platinum, and silver, particularly when in the precipitated or spongy state, act m violently, and cause a great disengagement of heat. A slightly acid solution of t peroxide is less amenable to the action of these agents than is the pure aqueous so tion; alkalis on the other hand facilitate the decomposition. The action of the abo mentioned bodies in causing the decomposition of the peroxide is termed catalyt Its nature, however, is not at present understood.

c. But the most remarkable circumstance connected with peroxide of hydrogen is property of acting as a reducing agent. When peroxide of hydrogen, or its analog peroxide of barium, is added to any one of the following substances, namely, the p toxides of silver or mercury, the peroxides of manganese or lead, the chromic, perma ganic, and ferricyanic acids, or their salts, not only is oxygen evolved from t peroxide of hydrogen, but also from the other oxidised body. Several of these reacti were noticed by Thénard in 1818, but they were first minutely examined a explained by Brodie in 1850 (Phil. Trans. 1850, p. 759; Chem. Soc. Qu. J. iv. 19 further, Chem. Soc. Qu. J. vii. 304). In accordance with his views, it seems that t second atom of oxygen in the peroxides of hydrogen and barium is not merely retai in an unstable state of combination, but that it is, by association with the oxide of electro-positive element, like hydrogen or barium, thrown into a polar state, oppos to the polar state of the oxygen in unstable protoxides, and to that of the loos combined oxygen in the more or less chlorous peroxides. Hence when the perox of hydrogen or barium is brought into relation with one or other of these oxygeni compounds, the two oppositely polarised oxygens unite with one another, as indica in the following formulæ:—

$$\overset{+}{\mathrm{Mn}}\overline{\mathrm{OO}} + \overset{+}{\mathrm{H}^2}\overline{\mathrm{OO}} = \overset{+}{\mathrm{Mn}}\overline{\mathrm{O}} + \overset{+}{\mathrm{H}^2}\overline{\mathrm{O}} + \overset{+}{\mathrm{O}}\overline{\mathrm{O}}$$

$$\overset{+}{\mathrm{Ag}}\overline{\mathrm{Ag}}\overline{\mathrm{O}} + \overset{+}{\mathrm{H}^2}\overline{\mathrm{OO}} = \overset{+}{\mathrm{Ag}}\overline{\mathrm{Ag}} + \overset{+}{\mathrm{H}^2}\overline{\mathrm{O}} + \overset{+}{\mathrm{O}}\overline{\mathrm{O}}$$

$$\overset{+}{\mathrm{Cr}^2}\overline{\mathrm{O}^3}\overline{\mathrm{O}^3} + \overset{+}{\mathrm{H}^6}\overline{\mathrm{O}^3}\overline{\mathrm{O}^3} = \overset{+}{\mathrm{Cr}^2}\overline{\mathrm{O}^3} + 3\overset{+}{\mathrm{H}^2}\overline{\mathrm{O}} + 3\overset{+}{\mathrm{O}}\overline{\mathrm{O}}$$

$$\overline{\mathrm{I}^2} + \overset{+}{\mathrm{H}^2}\overline{\mathrm{OO}} = 2\overset{+}{\mathrm{H}}\overline{\mathrm{I}} + \overset{+}{\mathrm{O}}\overline{\mathrm{O}}$$

Brodie has shown that, in the third and fourth reactions, the amounts of oxygen free correspond exactly with the above expressions. In the other two reactions, so additional oxygen is set free catalytically, from the decomposition of the peroxide *per se*. For finely-divided metallic silver has the property of decomposing peroxide hydrogen catalytically, whence the oxygen liberated according to the second equati has not been found to constitute more than 49, instead of 50, per cent. of the to quantity of oxygen evolved. It is observable that in no case can the oxygen from t peroxide constitute less than one-half of the total oxygen liberated. The above actions are perfectly comparable with admitted reactions showing the formation hydrogen and the alcohol-radicles (see CHEMICAL AFFINITY i. 857), for example:—

$$\overset{+}{\mathrm{Cu}^2}\overline{\mathrm{H}^2} + 2\overset{+}{\mathrm{H}}\overline{\mathrm{Cl}} = \overset{+}{\mathrm{Cu}^2}\overline{\mathrm{Cl}^2} + 2\overset{+}{\mathrm{H}}\overline{\mathrm{H}}.$$

$$\overset{+}{\mathrm{Zn}}(\overline{\mathrm{C}^2\mathrm{H}^3})^2 + 2(\overset{+}{\mathrm{C}^2}\overline{\mathrm{H}^3})\overline{\mathrm{I}} = \overset{+}{\mathrm{Zn}}\overline{\mathrm{I}^2} + 2(\overset{+}{\mathrm{C}^2}\overline{\mathrm{H}^3})(\overline{\mathrm{C}^2\mathrm{H}^3}).$$

Schönbein, apparently unaware of Brodie's researches, has recently drawn attenti to the phenomena of deoxidation effected by the peroxides of hydrogen and bariu and has shown that ozone is rendered inactive by them. He regards ozone as perm nently negative oxygen, $\overline{\mathrm{O}}$, which can form ozonides of silver, of manganous oxide, & and, in the above reaction, is neutralised by the permanently positive oxygen *antozone*, $\overline{\mathrm{O}}$, of the peroxide of hydrogen; whereas, according to Brodie, the polarity the oxygen depends upon the nature of the body with which it is associated, and manifested only at the instant of its disassociation. (Schönbein, Verhandl. d. natu Gesellsch. in Basel. ii. 113, 463, 472; Ann. Ch. Pharm. cviii. 157; J. pr. Chem. lxx 257, 263; lxxx. 266, 275; lxxxi. 1; lxxxiii. 86; Jahresber. 1858, p. 58; 1859, p. 6 1860, p. 54; 1862, p. 96.)

Schönbein has confirmed the observations of Meidinger and others, that peroxide hydrogen may sometimes be detected in water which has undergone electrolysis. seems also to have shown that traces of peroxide of hydrogen are produced in ma

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cases of slow oxidation occurring in the presence of moisture; for example, those of phosphorus, ether, zinc, &c. This production of peroxide of hydrogen he considers to be correlative of the other oxidation. Thus when moist zinc-filings are oxidised by exposure to air, a quantity of peroxide of hydrogen, which may be dissolved out by water and submitted to chemical tests, is formed, according to the following equation:

$$\overset{+}{Zn}^2 + 2\overset{+}{H}^2\overset{-}{O} + 2\overset{+}{H}^2\overset{-}{O} + 2\overset{+}{O}\overset{-}{O} = \overset{+}{Zn}\overset{+}{H}^2\overset{-}{O}^2 + \overset{+}{Zn}\overset{+}{H}^2\overset{-}{O}^2 + 2\overset{+}{H}^2\overset{-}{O}\overset{+}{O}.$$

Peroxide of hydrogen, even in a very dilute state, may be recognised either by its oxidising or by its reducing properties. Thus it decolorises a solution of indigo, especially in the presence of sulphate of iron, which apparently serves to convey the oxygen from the peroxide to the indigo; and similarly it liberates iodine from a solution of iodide of potassium, starch, and sulphate of iron. On the other hand, it decolorises a solution of permanganate of potassium by reduction, and causes a blue precipitate in a solution containing sesquichloride of iron and ferricyanide of potassium. It eventually reduces chromic acid to the state of chromic hydrate, but its first action is to produce, by oxidation, a very unstable perchromic acid. This compound, which has a deep blue colour, is readily soluble in ether, and its ethereal solution has a certain degree of stability; so that the presence of peroxide of hydrogen in any liquid may be ascertained by mixing it with ether, and then adding a few drops of a solution of chromic acid, whereby the ether assumes a bright blue colour.

The compound radicle, peroxide of hydrogen HO, is equivalent to the simple radicle chlorine Cl, and in a great number of reactions is exchangeable for chlorine and its congeners. One of the most generally useful modes of oxygenating different compounds consists in first substituting a halogen in exchange for hydrogen, and then, by means of water, substituting peroxide of hydrogen in exchange for the halogen. Thus, by the action of bromine upon acetic acid, we obtain bromacetic acid:—

$$C^2H^4O^2 + Br^2 = C^2H^3BrO^2 + HBr.$$

Then, by the action of water upon bromacetic acid, we obtain glycollic, or oxyacetic acid:—

$$C^2H^3BrO^2 + H.HO = C^2H^3(HO)O^2, \text{ or } C^2H^4O^3 + HBr.$$

(*Odling's Manual of Chemistry*, p. 124.)

Trioxide of Hydrogen. H^2O^3.—This, according to Baumert (Pogg. Ann. lxxxix. 38), is the composition of Ozone (*q. v.*)

HYDROGEN, PHOSPHIDES OF. Three of these compounds are known, viz. phosphoretted hydrogen gas, PH^3, liquid phosphide of hydrogen, PH^2, and the solid phosphide, P^8H.

1. **Phosphoretted Hydrogen** or **Phosphamine.** PH^3.—This gas, the analogue of ammonia, is produced by the spontaneous decomposition of phosphorised organic bodies, decaying fish for example. Its natural evolution appears to be the cause of *ignes fatui* and similar luminous appearances. The gas is also liberated in many chemical reactions, but it is very difficult to obtain pure, being always mixed with a greater or lesser proportion of free hydrogen, and frequently with the vapour of liquid phosphide of hydrogen, which renders it spontaneously inflammable, a property which it does not possess when free from the liquid phosphide. The spontaneously inflammable gas was discovered in 1789 by Gengembre (Crell. Ann. i. 450), and the non-spontaneously inflammable gas by Davy some years later.

Production of the spontaneously inflammable gas. 1. The compounds of phosphorus with the alkali-metals are resolved, in contact with water, into an alkaline hypophosphite and phosphoretted hydrogen. An impure phosphide of calcium is generally used for the purpose, prepared by heating phosphorus with lime (i. 719). When it is thrown into water, spontaneously inflammable phosphoretted hydrogen is slowly liberated, and the bubbles of gas, as they reach the surface, take fire, burn with a highly luminous flame, and produce thick clouds of white smoke, which, in a quiet atmosphere, ascend in the form of successive gradually expanding rings.

2. Phosphide of zinc, tin, or iron, with aqueous sulphuric or hydrochloric acid, yields a metallic sulphate or chloride and phosphoretted hydrogen gas.

3. Phosphorus heated in an aqueous solution of a fixed alkali, yields phosphoretted hydrogen gas, together with a hypophosphite and phosphate of the alkali-metal. Such an action is exerted by potash, soda, lithia, baryta, strontia, and lime, and, according to Raymond, by oxide of zinc and protoxide of iron. The primary decomposition yields phosphoretted hydrogen and hypophosphite; thus with lime-water:—

$$3CaH^2O^2 + P^8 + 6H^2O = 3CaH^4P^2O^4 + 2PH^3$$

Hydrate of calcium. Hypophosphite of calcium.

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from the very beginning of the action, the phosphoretted hydrogen gas is mixed
n more or less free hydrogen, and there is likewise a certain quantity of phosphate
duced; and as the boiling is continued and the solution becomes more concentrated,
quantity of hydrogen gas continually increases, because a greater and greater
ntity of the alkaline hypophosphite is resolved, by boiling in the alkaline liquid
hydrogen and an alkaline phosphate, *e.g.*:

$$\underset{\text{Hypophosphite of potassium.}}{KH^2PO^2} + 2KHO = \underset{\text{Phosphate of potassium.}}{K^3PO^4} + H^4.$$

s secondary decomposition takes place especially with the hypophosphites of the
e alkali-metals; hence solutions of the alkaline earths are best adapted for the
paration of pure phosphoretted hydrogen.
. When hypophosphites are heated, phosphoretted hydrogen is evolved, generally of
more inflammable, more rarely of the less inflammable variety, mixed with a
ain quantity of vapour of phosphorus and free hydrogen gas. (H. Rose.)
The non-spontaneously inflammable gas is produced—1. When hypophosphorous or
sphorous acid is heated, these acids being then resolved into phosphoric acid and
sphoretted hydrogen, which may be collected over water:

$$\underset{\text{Hypophosphorous acid.}}{2H^3PO^2} = PH^3 + H^3PO^4.$$

$$\underset{\text{Phosphorous acid.}}{4H^3PO^3} = PH^3 + 3H^3PO^4.$$

ording to Dumas and H. Rose, the first portions of gas evolved by this process are
e, but the later portions contain a considerable quantity of free hydrogen. The
sphorous acid should be gently heated in a flask of hard glass, as when softer glass
sed, a phosphite of alkali-metal is frequently formed, which is decomposed by the
t and yields free hydrogen. The mixture of phosphorous and phosphoric acids,
metimes called *phosphatic acid*, which is produced when phosphorus is left to oxidise
wly in moist air, may be used for the purpose. By the application of a stronger
t, hypophosphites, as well as hypophosphorus itself, yield phosphoretted hydrogen,
the gas produced from the salts is usually spontaneously inflammable and mixed
h free hydrogen.—2. When zinc or iron is dissolved in aqueous phosphorous acid,
inc in a mixture of aqueous phosphorous acid and sulphuric acid, or when phos-
ric acid is deoxidised by potassium or sodium (Wöhler).—3. When phosphorus is
led with hydrate of potassium and alcohol, the non-inflammable gas is evolved, mixed
h hydrogen gas and alcohol vapour, and there remains hypophosphite of potassium
a small quantity of phosphate, together with excess of potash (H. Rose).—4. When
sphide of calcium is decomposed by concentrated hydrochloric acid (Dumas).—
Phosphorus, under the influence of light, decomposes water, producing phosphoric
de [? red phosphorus] and phosphoretted hydrogen gas, which remains dissolved in
water.

Spontaneously inflammable phosphoretted hydrogen may be freed from the com-
und PH^3, and rendered non-inflammable, by passing it through a freezing mixture of
and salt; but according to Graham, the addition of a minute quantity of nitric
de gas will confer on it the property of spontaneous inflammability [? by oxidising
mall quantity of it to PH^2]. It is also deprived of its spontaneous inflammability
exposure to sunlight, by contact with charcoal and other pulverulent bodies, and by
nixture with the vapours of ethylic chloride, ethylic oxide, alcohol, turpentine, &c.
Properties. Phosphoretted hydrogen is a colourless gas of specific gravity 1·214
erred to air, or 17·25 referred to hydrogen (Dumas); by calculation for a condensation
2 volumes it is $\frac{31 + 3}{2} = 17$. It is liquefiable, but has not yet been solidified
98). It smells like stinking fish, or rather the fish in a state of decomposition have
odour of the gas, since they evolve it. It is sparingly soluble in water, more so in
ohol, ether, and volatile oils. Neither the gas nor its solutions have any action upon
e or red litmus paper.
Decompositions.—1. When a series of *electric sparks* is passed through the gas, two
umes of it are converted, with deposition of phosphorus, into three volumes of hy-
gen.—2. Most *metals* heated in the gas combine with the phosphorus, and liberate
hydrogen.—3. Phosphoretted hydrogen is very inflammable, burning with a
lliant flame and evolving a white smoke of phosphoric acid. A mixture of the non-
ntaneously inflammable gas and *oxygen* standing over water is gradually absorbed,
h production of phosphorous acid. The mixture of the two gases, though changing
y gradually at ordinary pressures, undergoes, when suddenly rarefied, an instan-
eous decomposition, attended with violent explosion.—4. Phosphoretted hydrogen

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quickly reduces many oxidised bodies, *e.g. nitric oxide, nitric acid, sulphurous anhydride* and *sulphuric acid*. It is completely absorbed by solutions of *hypochlorous acid* and the alkaline hypochlorites.—*5.* It precipitates the solutions of many *metallic salts* those of *lead* very slowly, those of *copper* more quickly, and those of the *noble metals* most quickly of all. The precipitates, save those produced with mercury-salts, are black or dark-coloured. They consist of metallic phosphide, as in the case of copper; of mixed phosphide and metallic salt, as in the case of mercury; or of reduced metal, as in the case of silver and gold. Solution of sulphate of copper is often used for estimating the proportion of free hydrogen in ordinary phosphoretted hydrogen, by observing the quantity of gas which it leaves unabsorbed.

6. Chlorine, bromine, and *iodine* decompose phosphoretted hydrogen, abstracting its hydrogen. If in excess, they also combine with its phosphorus to form the respective chlorides, bromides, and iodides, or their products of decomposition with water. When bubbles of phosphoretted hydrogen are introduced into a receiver of chlorine, they inflame with a sharp explosion, producing hydrochloric acid and pentachloride of phosphorus. Many metallic chlorides also, when gently heated in phosphoretted hydrogen, produce hydrochloric acid gas—the volume of which is three times as great as that of the phosphoretted hydrogen—and a metallic phosphide; or else hydrochloric acid, free phosphorus and free metal.—*6. Sulphur* heated in phosphoretted hydrogen forms sulphide of hydrogen and sulphide of phosphorus.

Phosphoretted hydrogen, though devoid of any alkaline reaction, is in other respects closely analogous to ammonia; hence it is called phosphamine. Thus it unites directly with *hydriodic acid* to form the hydriodate of phosphamine, $PH^3.HI$, or iodide of phosphonium, PH^4I, and a corresponding compound with *hydrobromic acid*. Moreover, like ammonia, phosphamine unites with the perchlorides of many metals, forming white saline bodies of similar constitution to the ammonio-chlorides.

Hydriodate of Phosphamine may be obtained by the direct combination of the two gases, or by adding a little water to equal atomic proportions of iodine, ground up with pounded glass, and phosphorus cut up into small pieces. Vapours of hydriodate of phosphamine mixed with hydriodic acid are immediately given off, the former condensing as a crystalline deposit. A better mode of preparation is, however, that given by Hofmann, which consists in gently heating iodine in a current of dry phosphoretted hydrogen gas:

$$4PH^3 + I^4 = PI^2 + 3H^4PI.$$

The salt crystallises in cubes, which fuse when moderately heated, and out of access of air, may be sublimed without change. They are deliquescent and are decomposed by water into hydriodic acid and phosphamine.

Hydrobromate of Phosphamine, $PH^3.HBr$ or PH^4Br, is also obtained by direct combination, or it may be prepared by introducing bromide of silicon, together with a little water, into a jar of phosphoretted hydrogen (Serullas). It crystallises in cubes, sometimes transparent, sometimes opaque; boils at about 30°. Vapour-density, obs. = 1·906; calc. (2 vol.) = 3·98; hence this compound affords an example of anomalous vapour-density, probably arising from disassociation (i. 469; ii. 816).

Derivatives of Phosphamine.—The three atoms of hydrogen, like those of ammonia, in phosphamine, may be replaced by metals or organic radicles, *e.g. tricupric phosphide,* $P^2(Cu'')^3$; *tricuprous phosphide,* $P^2(Cu^2)^3$; *triethylphosphine,* $P(C^2H^5)^3$. The metallic phosphamines are obtained by passing phosphoretted hydrogen gas over the heated metals or their oxides, or into solutions of the respective salts, or by treating the metals directly with phosphorus. (See Phosphides.)

The organic derivatives of phosphamine constitute a more important class of compounds, exactly analogous to the tertiary monamines (i. 175). Phosphorus-bases analogous to the primary and secondary monamines have not yet been obtained. The tertiary phosphines are obtained by decomposing the zinc-compounds of the alcohol-radicles with trichloride of phosphorus, *e.g.*:

$$\underset{\text{Zinc-ethyl.}}{3Zn(C^2H^5)^2} + 2PCl^5 = 3ZnCl^2 + \underset{\substack{\text{Triethyl-}\\\text{phosphine.}}}{2P(C^2H^5)^3}.$$

They are volatile strongly basic compounds, which unite readily with acids, forming crystalline salts, analogous to those of triethylamine, &c. Triethylphosphine (like triethylamine) unites directly with iodide of ethyl, forming the iodide of tetrethylphosphonium, $P(C^2H^5)^4I$, from which, by the action of moist oxide of silver, the hydrate of tetrethylphosphonium, $P(C^2H^5)^4HO$, may be obtained. (See Phosphorus-bases.)

Liquid Phosphide of Hydrogen. This compound, which communicates spontaneous inflammability to phosphoretted hydrogen gas, was discovered by Paul Thénard (Ann. Ch. Phys. [3] xiv. *5*), and regarded by him as PH^2. By some chemists, however, it is supposed to contain oxygen as well as hydrogen, and to

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constitute the hydrogen representative of oxychloride of phosphorus, nam
It is produced, together with spontaneously inflammable phosphoretted hyd
by the action of water on phosphide of calcium (i. 719):

$$5PCa + 5H^2O = 5CaO + 5PH^2 \text{ (P. Thénard),}$$

and may be separated by passing the gas through a U-tube cooled by a freezi

Into the middle tubulure of a three-necked Woulfe's bottle, holding abou
inserted a glass tube 12 inches long and half an inch wide, so as to reach ne
bottom. To the second tubulure is adapted a tube twice bent at right an
tube dips into water and serves for a safety-tube. Into the third is fitted a
¼ inch diameter, immersed to the depth of 5 or 6 inches in a freezing mixture.
which projects above the freezing mixture is bent at a not very acute angle,
out at two points not far from each other and near the end, so that, at the conclu
operation, the liquid may be introduced into the intermediate part of the tul
parts which have been drawn out closed by the blowpipe. The apparatus
arranged, the bottle is three parts filled with water and placed in a water-b
to between 60° and 70°; the last-mentioned tube is closed; and a few drop
phide of calcium are thrown through the middle one into the bottle. The g
takes fire, and drives out the air through the safety-tube. The U-tube is
opened, and from 400 to 600 grains of phosphide of calcium gradually intro
the bottle: in a few minutes, oily drops of liquid are seen to collect in the
tube nearest to the bottle. The process must be stopped after 15 or 2
because water condenses in the tube, together with the phosphide of hyd
often stops it. The tube is now to be sealed at the narrowed neck nea
extremity, then removed from the bottle, and held by the finger (cov
caoutchouc to save the operator from being burnt) in such a position
remaining gas may escape; it is then warmed by the hand to cause the
liquid which have been separated by particles of ice to run together, and ag
in the freezing mixture to solidify the water, and prevent it running back.
effected, the liquid is made to flow towards the sealed end of the tube, and
neck of the tube is closed by the blow-pipe. A well-conducted operation yi
30 grains of liquid.

Liquid phosphide of hydrogen is colourless and does not solidify at −20°
40°, it appears to volatilise and to be decomposed at the same time; ref
strongly. It is insoluble in water. Alcohol and oil of turpentine appear t
it, but it quickly decomposes in the solution. It burns spontaneously in the
an intensely bright white flame, and produces dense white fumes. It com
spontaneous inflammability to 500 times its weight of phosphoretted hyd
All combustible gases are rendered spontaneously inflammable by admixture
phosphide of hydrogen.

By the action of light it is resolved into solid and gaseous phosphide of
$5PH^2 = P^2H + 3PH^3$. It is also decomposed, like peroxide of hydrogen,
with various substances. An indefinite quantity of liquid phosphide of hyd
be decomposed by a cubic centimetre of hydrochloric acid gas.

Solid Phosphide of Hydrogen. P^2H?—When spontaneously in
phoretted hydrogen is exposed to sunshine, a solid yellowish compou
posited on the sides of the glass, the gas at the same time losing its propert
taneous inflammability (Leverrier, Ann. Ch. Phys. lx. 175). The same
pound is obtained in larger quantity by treating liquid phosphide of hyd
hydrochloric acid, or by dissolving phosphide of calcium in strong hydroc
the liquid phosphide being then resolved into the solid and gaseous phosp
above). Hence spontaneously inflammable phosphoretted hydrogen passe
aqueous hydrochloric acid loses its spontaneous inflammability and yields a
solid phosphide.

This compound is insoluble in water and in alcohol. It dissolves in wa
with liberation of non-spontaneously inflammable phosphoretted hydrogen.
fire at about 150°. (P. Thénard, *loc. cit.*)

HYDROGEN, SELENIDE OF. H^2Se. *Selenhydric* or *Hydrose*
Selenietted Hydrogen.—A gaseous compound analogous to sulphydric acid
by the action of dilute hydrochloric or sulphuric acid on selenide of potassiu
other metals. It is colourless and inflammable, soluble in water, and cann
preserved over mercury. It has a most offensive, acrid odour, impairing o
stroying the sense of smell for several hours, and producing inflammation of th
aqueous solution absorbs oxygen from the air, and deposits selenium. It ha
taste, a slight acid reaction, and gives with the solutions of most metals, p
consisting of metallic selenides, those of manganese, zinc, and cerium b
coloured, the remainder brown or black. (Berzelius.)

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HYDROGEN, SULPHIDES OF. Sulphur unites with hydrogen in two proportions, forming the protosulphide, H^2S; and the persulphide, probably HS or H^2S^2.

Protosulphide of Hydrogen. H^2S. *Sulphydric acid. Hydrosulphuric acid. Hydrothionic acid. Sulphuretted hydrogen.*—This compound may be formed in small quantity by burning sulphur-vapour in hydrogen gas, or hydrogen gas in sulphur-vapour, precisely as its analogue, water, is produced under similar circumstances from oxygen and hydrogen.

The gas is ordinarily prepared by the action of an acid—sulphuric or hydrochloric for instance—upon a metallic sulphide, usually that of iron or antimony. Dilute sulphuric acid acts readily upon sulphide of iron, producing, even in the cold, a rapid effervescence of sulphydric acid:

$$FeS + H^2SO^4 = H^2S + FeSO^4.$$

Inasmuch as sulphide of iron is an artificial product, nearly always containing an excess of metallic iron in admixture, the sulphydric acid obtained from it is generally contaminated with free hydrogen; but the native crystalline trisulphide of antimony, being a normal sulphide, when acted upon by boiling hydrochloric acid, yields the gas in question in a very pure state, thus:

$$Sb^2S^3 + 6HCl = 3H^2S + 2SbCl^3.$$

The sulphydric acid obtained from either of these sources may be passed through a small quantity of water to wash it, and over chloride of calcium to render it dry. It may be collected in the gaseous state over mercury, or absorbed at once into water, in which it is very soluble.

Sulphydric acid, more frequently sulphydrate of ammonia, results from the spontaneous decomposition of sulphuretted organic compounds; also from treating non-sulphuretted organic compounds with sulphur. Reinsch recommends a laboratory process for obtaining pure sulphydric acid, by heating in a glass flask a mixture of equal parts of sulphur and suet.

Sulphydric acid occurs naturally, and is not unfrequently evolved from fumaroles and volcanoes. It exists to a considerable extent in certain mineral waters known as hepatic waters, those of Harrogate, for instance. It is also produced spontaneously in many waters charged with organic matter and sulphates, usually sulphate of calcium.

Properties.—At ordinary temperatures and pressures, sulphydric acid is gaseous. It may be obtained in the liquid state by generating it in one limb of a sealed tube, from sulphuric acid and sulphide of iron freed from metallic iron, and condensing it in the other limb, which should be immersed in a freezing mixture, that of ice and salt being sufficient for the purpose; or liquid persulphide of hydrogen may be gently heated in one limb of a bent sealed tube, when it breaks up into sulphur, which remains, and sulphydric acid, which may be condensed in the other limb kept cool for the purpose. By the powerful refrigeration resulting from the evaporation *in vacuo* of a mixture of solid carbonic anhydride and ether, it may be solidified. Solid sulphydric acid, or sulphur-ice, is a white transparent mass which melts at $-85{\cdot}5°$. Liquid sulphydric acid is a colourless transparent fluid, remarkable for its extreme thinness or mobility. Its specific gravity is 0·9 compared with that of water as 1. Sulphydric acid gas is transparent and colourless. Its density is somewhat greater than that of atmospheric air, being 1·1781 referred to air, or 17 referred to hydrogen, as unity. It is characterised by an offensive odour resembling that of rotten eggs, the smell of which indeed is due to the evolution of this gas, or of its compound with ammonia. In the concentrated state it cannot be breathed with impunity, and even when much diluted it frequently gives rise to nausea and vertigo. An atmosphere containing $\frac{1}{10}$ per cent. of this gas proves fatal to the lower animals.

Sulphydric acid is readily inflammable. It burns with a bluish flame, forming sulphurous acid, and frequently deposits free sulphur from the imperfect access of oxygen. Most *metals* when heated in the gas absorb the sulphur and leave the hydrogen. *Cadmium* or *tin* is generally used for the purpose: $Cd^2 + H^2S = Cd^2S + H^2$. The bulk of the resulting hydrogen is equal to that of the original sulphydric acid; or, in other words, two volumes of sulphydric acid, H^2S, when acted on by metal, leave two volumes of hydrogen. Sulphydric acid in the gaseous state, or dissolved in water, is decomposed by *chlorine*, *bromine*, and *iodine*, with liberation of sulphur and formation of hydrochloric, hydrobromic, and hydriodic acids respectively. In a similar manner it is decomposed, with liberation of sulphur, by nearly all *oxidising agents;* and even *sulphurous acid*, which usually acts as a deoxygenant by absorbing oxygen, acts in this case as an oxygenant by affording oxygen:

$$2H^2S + SO^2 = 2H^2O + S^3.$$

In some cases, however, a peculiar sulphur-acid, the pentathionic, is formed in addition, thus

$$5H^2S + 5SO^2 = 4H^2O + H^2S^5O^6 + S^3.$$

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A saturated aqueous solution of sulphydric acid contains about three times its volume of the gas. It is a clear colourless liquid, having a slight acid reaction, and the smell and taste of the gas. It is gradually decomposed by exposure to air, its hydrogen being oxidised into water and its sulphur set free. Sulphydric acid when burnt yields sulphurous acid, as we have seen; but moist sulphydric acid, mixed with air or oxygen, and exposed to a moderately warm temperature, from 40° to 90°, is converted into sulphuric acid.

Sulphydric acid, like water, is capable of giving up the half or the whole of its hydrogen in exchange for a metal, the resulting compound being a sulphydrate or a sulphide, according as 1 or 2 at. H are thus replaced; *e. g. sulphydrate of barium*, BaHS; *sulphide of barium*, Ba^2S. It is only the alkali-metals and alkaline-earth-metals that appear to be capable of forming definite sulphydrates, all of which are soluble in water and crystallisable. The heavy metals form insoluble sulphides, which may be derived from a single or a multiple molecule of sulphydric acid, just as the corresponding oxides are derived from a single or multiple molecule of water: *e. g. sulphide of silver*, Ag^2S; *mercuric sulphide*, Hg^2S or $Hg''S$; *trisulphide of antimony*, Sb^2S^3, &c. (See SULPHIDES and SULPHYDRATES.)

The sulphides of the heavy metals are precipitated from solution of metallic salts by sulphydric acid or an alkaline sulphide or sulphydrate:

$CuSO^4$	+	H^2S	=	H^2SO^4	+	CuS.
$2SbCl^3$	+	$3H^2S$	=	6HCl	+	Sb^2S^3.
$FeSO^4$	+	$NH^4.H.S$	=	$NH^4.H.SO^4$	+	FeS.

Some metals are precipitated in this manner from their acidified solutions by sulphydric acid gas or its aqueous solution; others only from neutral or nearly neutral solutions, by an alkaline sulphide or sulphydrate, in some cases as sulphides (nickel, cobalt, manganese, zinc, uranium), in others as hydrates (chromium, and the metals of the earths proper); and and lastly, there are some metals, namely those of the alkalis and alkaline earths, which are not precipitated either by sulphydric acid or an alkaline sulphydrate. On these reactions is founded a division of the metals into groups, which forms the basis of the mode of separating them usually adopted in analysis. (See ANALYSIS, INORGANIC, i. 217.)

Sulphydric acid is recognised by the black discoloration it produces on paper moistened with solutions of lead or bismuth, and by the black tarnish it gives to silver-foil.

Persulphide of Hydrogen. H^2S^2?—This compound seems to be the sulphur-representative of peroxide of hydrogen, which it much resembles in its properties. It is made by gradually adding the solution of a persulphide of alkaline earth- or alkali-metal to an excess of hydrochloric acid diluted with twice its bulk of water:

$$CaS^5 + 2HCl = CaCl^2 + H^2S^2 + S^3.$$

The persulphide of hydrogen is formed without any evolution of gas, and separates as a yellowish oily fluid, heavier than water. It has the property of dissolving sulphur to a considerable extent, owing to which circumstance its composition has not been satisfactorily established. Persulphide of hydrogen has a peculiar, sulphurous, disagreeable odour. It produces superficial white eschars on the skin and mouth. It is insoluble in water, but soluble in ether, forming a solution which soon decomposes and deposits crystals of sulphur. It is readily inflammable, and burns with a blue flame. It is possessed of bleaching properties analogous to those of peroxide of hydrogen.

Persulphide of hydrogen is a very unstable substance, and, especially at increased temperatures, undergoes spontaneous decomposition into sulphydric acid and sulphur. By effecting this decomposition in a sealed tube, liquid sulphydric acid may be obtained (p. 203). The stability of the persulphide is increased by the presence of moderately strong acids. Alkalis, on the other hand, promote its decomposition. Hence if, in its preparation, the hydrochloric acid be added to the alkaline persulphide, instead of the persulphide to the acid, no persulphide of hydrogen, but only sulphydric acid and sulphur will be obtained. Under the influence of catalytic agents, such as finely-divided platinum, gold, iridium, and charcoal, which effect the similar decomposition of peroxide of hydrogen into oxygen and water, persulphide of hydrogen undergoes an instantaneous decomposition into sulphur and sulphydric acid. It reduces peroxide of manganese and the oxides of silver and gold, the last two with great violence, and frequently even with ignition. (*Odling's Manual of Chemistry.*)

HYDROGEN, TELLURIDE OF. H^2Te. *Tellurhydric* or *Hydrotelluric acid. Telluretted hydrogen.*—This compound is evolved as a gas, when certain metallic tellurides, the telluride of zinc being generally used, are treated with hydrochloric acid:

$$ZnTe + 2HCl = H^2Te + ZnCl^2.$$

It closely resembles its analogues, sulphydric and selenhydric acids, smells very much like the former, burns with a blue flame, has a slight acid reaction, and dissolves in

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water, forming a colourless liquid which deposits tellurium when exposed to the air. It precipitates most metals from their solutions in the form of tellurides (*q. v.*)

HYDROHALITE. A native hydrated chloride of sodium, $NaCl.2H^2O$. (Dana, ii. 506.)

HYDROKINONE. See HYDROQUINONE.

HYDROLEIC ACID. See OLEIC ACID.

HYDROLITE. Syn. with GMELINITE (ii. 924).

HYDROMAGNESITE. *Hydrated carbonate of magnesium*, $4MgO.3CO^2.4H^2O = 3(MgCO^3.H^2O).MgH^2O^2$ or $3(MgH^2CO^4).MgH^2O^2$.—It occurs native in small monoclinic crystals, usually acicular or bladed and tufted, also amorphous or as a chalky crust. Specific gravity = 2·145. Hardness of crystals = 3·5. Lustre vitreous to silky or sub-pearly; also earthy. Colour and streak white. It is found in serpentine at Hrubschitz in Moravia; near Kumi in Negroponte; at Hoboken, New Jersey, and other localities in North America (Dana, ii. 457). A specimen from Texas, Lancaster county, Pennsylvania, analysed by Smith and Brush (Sill. Am. J. [2] xv. 207), gave 36·00 per cent. CO^2, 43·96 MgO, 19·68 water, and 0·36 silica. Artificially prepared hydrocarbonate of magnesium has sometimes the same composition.

HYDROMAGNOCALCITE. Syn. with HYDRODOLOMITE.

HYDROMARGARIC and **HYDROMARGARITIC ACIDS.** Acids of doubtful constitution, which Frémy obtained by treating olive-oil with strong sulphuric acid. (See MARGARIC ACID and PALMITIC ACID.)

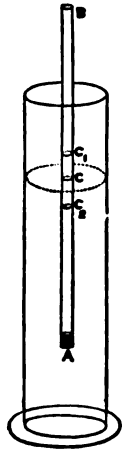
HYDROMELLONE. See MELLONE.

HYDROMETER (ὕδωρ, water; μέτρον, measure). *Gravimeter, Pèse-liqueur;* on the Continent, most commonly called the *Areometer* (ἀραιός, rare, subtle). An instrument which, on being placed in a liquid, shows its specific gravity, either by direct inspection, or by simple adjustment and calculation.

Its action depends on the simple principle of hydrostatics, that a floating body must displace its own weight of liquid. The truth of this principle is seen if we consider that any part of a mass of liquid at rest must be supported by the pressure of the surrounding liquid, and will certainly continue to be supported, so long as it has the same weight and volume: hence it may be conceived to become solid without altering the conditions of equilibrium. Now weight is mere downward pressure, and the solid immersed in a liquid need not weigh so much as an equal volume of liquid, provided that the difference is exactly made up by downward pressure, or weight communicated from another part of the solid, above the surface of the liquid.

Thus, in *fig.* 557, suppose the solid AB to have the same weight as a volume of water equal to the volume of the part AC. When placed in water, the solid will sink up to the point C: for the upward pressure of the water, which usually supports a volume of water equal to AC, will then be exactly sufficient to support the weight of the solid AB. If we now place AB in a liquid of less specific gravity, the weight of AB will be greater than the weight of the volume AC of the liquid, and equal, for instance, to the weight of the volume AC_1. Then by similar reasoning, AB will sink into this lighter liquid up to the point C_1. Again, if AB sink in a third liquid only up to the point C_2, it is obvious as before, that the volume of liquid AC_2 is equal in weight to the solid AB.

Fig. 557.



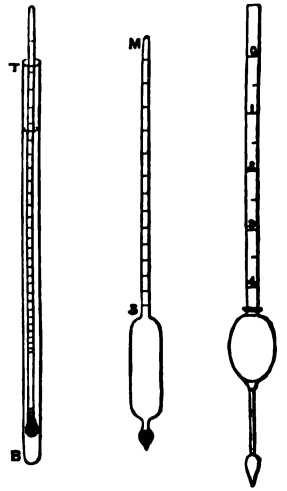
Now the specific gravities of bodies are, by definition, in the proportion of the weights of equal volumes of the bodies, or, which is the same, in the inverse proportion of the volumes of equal weights. In other words, the specific gravity is less, as it requires a larger volume to make a given weight. Now the volumes AC, AC_1, AC_2, of the respective liquids are all of one weight, that of the solid AB: hence the specific gravities have the inverse proportion of AC, AC_1, AC_2, or if we assume the first (water) to have the specific gravity 1·00, the specific gravities of the others are $\frac{AC}{AC_1}, \frac{AC}{AC_2}$.

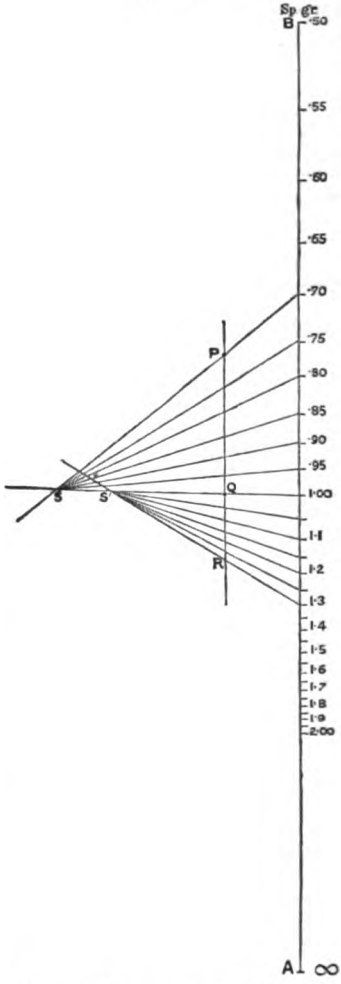
The hydrometers commonly used do not differ from the solid body AB above described, except that the part which meets and cuts the surface of the liquid is usually of very narrow section, in order that slight differences in the density of the liquid may cause the hydrometer to rise or sink through a considerable space. The form of those parts of the hydrometer below the liquid has no effect upon the accuracy of the result, but for convenience the lower parts are usually much expanded, in order that they may be proportionally shorter. Several different forms of the hydrometer are shown in *figs.* 558, 559, 560. The hydrometer in *fig.* 558 would indicate specific gravities differing through a considerable range, but without much accuracy. It is accompanied by a tube TB, which holds the liquid under examination. That in *fig.* 559, on the contrary, has

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a very slender stem (SM), and would indicate with great accuracy any specific gravit within a certain narrow range. Hydrometers are usually made of light glass tu and bulbs blown in a single piece. The chief part of the weight is given by small sh or mercury, carefully adjusted so that the instrument shall sink to a conveni depth in the required liquids, and then sealed up in a small bulb at the lowerm extremity. In other cases, the hydrometer is made of thin gilt brass or silver, as *fig.* 560, but the weight is still placed below, in order that the instrument may fl upright and stiffly.

Fig. 558. *Fig.* 559. *Fig.* 560. *Fig.* 561.





Graduation.—We have yet to consider the nature of the graduation on the stem of any hydrometer which is to give by inspection the specific gravity of the liquid in which it floats. Reverting to *fig.* 557, let the distance AC to which the hydrometer sinks be successively x_0, x_1, x_2, &c. when AB stands in liquids of the densities ρ_0, ρ_1, ρ_2, &c.

Then $\frac{x_1}{x_0} = \frac{\rho_0}{\rho_1}$, $\frac{x_2}{x_0} = \frac{\rho_0}{\rho_2}$, &c. Of these quantities let ρ_0 be the density of distilled water at the temperature 62° F., which we assume as 1·00; call the corresponding length x_0, the unit of length. Then $x_1 = \frac{1}{\rho_1}$, $x_2 = \frac{1}{\rho_2}$ &c., and $x_1 - x_2 = \frac{1}{\rho_1} - \frac{1}{\rho_2}$. Thus we see that equal differences of specific gravity are indicated, not by any equal intervals on the scale, but by the differences of the reciprocals of those specific gravities, or by quantities proportional to them. The scale which must then be employed is to be obtained by calculation, and its character is shown with some accuracy in the divi line AB *fig.* 561.

Until recently, indeed, it was customary to graduate the stem of every hydrome into some series of equal divisions arbitrarily chosen, and the indications were eit used conventionally, without reference to specific gravity at all, or the correspondi specific gravity was ascertained by calculation or reference to a table. It is obviou desirable, however, to adopt the true scale of specific gravities, since this can always constructed with facility and sufficient accuracy.

A mode of graduating hydrometers with accuracy, as practised by Mr. Ackland, described in the Reports of the Jurors of the Exhibition of 1851 (p. 25). It consi of the following processes:

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1. Ascertaining the exact position of three or more points of the scale, according as the stem of the hydrometer is more or less truly cylindrical.

2. Dividing with great accuracy a scale on boxwood, to show the specific gravities required to be indicated by the hydrometer.

3. Making a reduced copy of the boxwood scale, so as to form a scale, the points of which shall correspond with the ascertained points on the hydrometer-tube. The scale so formed on paper is ready to be engraved on the hydrometer.

For example, suppose it be required for a hydrometer to show specific gravities from 1·00 to 0·700. A bulb is chosen with a stem as uniform as possible, and three points—for instance, ·700, ·850, and 1·000—are ascertained as follows: Load the hydrometer till it sinks in distilled water of the temperature 62° to some marked point convenient for the degree 1·00; let the weight of the instrument then be x. To ascertain the point of the degree ·85, alter the weight of the hydrometer until it is $\frac{1{\cdot}00 \times x}{{\cdot}85}$, and placing it in water, mark where it is cut by the surface. Lastly, alter the weight to $\frac{1{\cdot}00 \times x}{{\cdot}70}$, and mark the point as before, which will correspond with the specific gravity ·700. The original weight x of the hydrometer may then be restored and the tube sealed. This method, requiring the use of no liquid but water, is very convenient, and was suggested to Mr. Ackland by Dr. Clarke of Aberdeen.

The remainder of Mr. Ackland's processes are performed by calculating the reciprocals of the specific gravities required, forming them into a scale, and then reducing this scale and transferring it to the glass tube by a dividing engine of peculiar and ingenious construction.

We have formed the following table of the reciprocals, and their differences. Intermediate degrees can easily be interpolated when necessary.

Specific gravity.	Reciprocal.	Difference of Reciprocals.	Specific gravity.	Reciprocal.	Difference of Reciprocals.
2·00	·500		1·25	·800	
		·013			·033
1·95	·513		1·20	·833	
		·013			·037
1·90	·526		1·15	·870	
		·015			·039
1·85	·541		1·10	·909	
		·015			·043
1·80	·556		1·05	·952	
		·015			·048
1·75	·571		1·00	1·000	
		·017			·053
1·70	·588		·95	1·053	
		·018			·058
1·65	·606		·90	1·111	
		·019			·065
1·60	·625		·85	1·176	
		·020			·074
1·55	·645		·80	1·250	
		·022			·083
1·50	·667		·75	1·333	
		·023			·096
1·45	·690		·70	1·429	
		·024			·109
1·40	·714		·65	1·538	
		·027			·129
1·35	·741		·60	1·667	
		·028			·151
1·30	·769		·55	1·818	
		·031			·182
			·50	2·000	

We shall now describe a graphical method which the chemist can easily use as a substitute for Mr. Ackland's dividing engine, so as to graduate his own hydrometers with accuracy. Draw a line AB (*fig.* 561) on a sheet of good paper, and lay off upon it, with exactness, as many of the reciprocal numbers or differences, given in the table, as are likely to be required within the range of the hydrometers to be graduated: this may easily be done with the aid of a decimal or diagonal scale and a pair of compasses. The absolute size of this scale is of no importance, except that the larger it is the more accurate will the result probably be.

Now suppose the points on a hydrometer have been determined for the specific gravities ·700, 1·00 and 1·30. Draw a line exactly parallel to AB, and measure off distances PQ, QR, equal to the absolute distances of the points on the hydrometric stem, placing the points P, Q, R, as nearly as possible opposite the specific gravities ·700, 1·00, 1·30, on the scale AB. Draw lines through P and the degree ·70, and through Q and the degree 1·00. If these lines never meet, the scale on PQ will be identical with that on AB. But suppose they meet in S: draw lines through S and the several degrees on AB between ·70 and 1·00. Then the intersections of these lines and PQ give the required points for the scale PQ. Next draw a line through R and the degree 1·3. If this also pass through the point S it will indicate that the stem of the hydrometer is perfectly uniform. But wherever S', the point of intersection of Q—1·00 and R—1·30 may be, draw lines from S', through the degrees of AB, giving by their intersection with QR the required points of graduation.

If necessary, other points besides P, Q, R, might, for the sake of accuracy, be

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determined on the stem of the hydrometer, and the graduation could still be perfo with but little extra trouble, from many successive points of intersection.

The hydrometer scale, when once obtained on paper, can be transferred to the stem of the instrument by the usual process of etching with hydrofluoric acid. glass must be covered with bees'-wax, and firmly fixed, at a proper distance, i same straight line with the divided scale, the degrees of which may then be easi accurately transferred by a beam-compass. For fuller directions on the meth graduating glass tubes, the reader must consult Bunsen's Gasometry (p. 25), als article ANALYSIS OF GASES in this Dictionary (i. 269). Were it desired oft graduate hydrometers, it would be best to engrave the scale AB (*fig.* 561) u glass plate, together with converging lines drawn through the degrees, and then it as Bunsen describes.

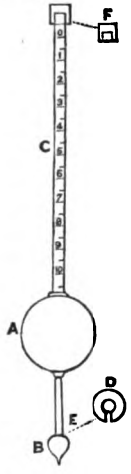
The smaller intervals of a hydrometer scale may always be subdivided into parts by estimation, or otherwise, without appreciable error.

The delicacy of the hydrometer may always be increased to an indefinite exte lessening the diameter of the stem; but in the same proportion it becomes more li in range, and troublesome to use. The adhesion of air-bubbles is a great sou discrepancy, especially in the metal instruments, and for this reason all hydrom should be made with as smooth and small a surface as possible.

Again, the attraction of the glass or metal stem for the water causes the surf water to rise up against the stem in a parabolic curve. This phenomenon alo preventing us from getting an exact reading, is almost enough to condemn the h meter as a standard instrument of measurement. Fortunately the hydrostatic ba and the specific gravity bottle are means of determining specific gravities unlimited accuracy and considerable ease. The hydrometer takes a subordinate and is chiefly employed in approximately determining the strength of solutio mixtures of liquids. It often effects a wonderful saving of time or trouble, an person frequently occupied with liquids of a variable strength or composition s have hydrometers suitably constructed in range and delicacy for testing them. treat the instrument as suitable for exact scientific measurement, and to investigat determine corrections for every little error which might arise, would be a mis We accordingly proceed to describe various well-known forms of the hydrometer, v are extensively used for practical purposes.

Sykes' *Hydrometer* is of importance because, by Act of Parliament (58 Geo c. 28; see also 3 & 4 Will. IV. c. 52 § 123) it is employed in the collection of th cise revenue of the United Kingdom levied upon spirituous liq of which of course the strength must be determined. It is ma brass (*fig.* 562) with a spherical bulb A, 1½ inch in diameter, a w (B) to sink it and maintain it upright in the liquor, and a flat form stem C, 8½ inches long, divided into ten parts, each of whi again divided into two parts. A series of nine weights of the fo accompany the instrument, having the proportions 10, 20, 30, 90. These weights are placed in succession at E, until the in ment is found to sink in the liquor up to some point of the di scale. The numerical reading of the scale at the point where cut by the surface of the liquor, added to the number on the w employed, gives the required result. But the temperature of liquor must also be observed, and the proportion of spirit it con ascertained by a table in which the variables are the degrees o hydrometer and thermometer.

Fig. 562.



The supernumerary weight F may be placed on the summit o stem, and then causes the hydrometer, loaded with the cir weight 60, to sink to the same point in pure water to which it w otherwise sink in proof spirits. Concerning the determinati the proportion of alcohol contained in a mixture with water ALCOHOLOMETRY (i. 81).

Jones' *Hydrometer* is an improvement on that of Sykes. It i companied by three detached weights, so that, according as thes used or not, the hydrometer may have four different degrees of we Corresponding to these are four separate scales on the sides o stem, which is made square for the purpose. A thermometer, also with four diff scales, is included in the lower part of the instrument, and the whole is so cont that the number of gallons in the 100 under or over *proof* may be read off.

The following formulæ apply to any hydrometer, as for instance Sykes' or Jone which weights are added below the liquid.

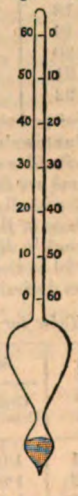
Let w = weight of hydrometer.
v = volume of hydrometer up to the bottom of the scale.
m = area of section of stem (supposed uniform).

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loaded with the weight w_1 sink to the degree x_1 of scale), and in liquid B, when loaded with w_2, ume of weight w_1.
,, w_2.
$V + v_1 + x_1.m.$
$V + v_2 + x_2.m.$
ume of A displaced is $W + w_1$.
B ,, $W + w_2$.
$+ v_2 + x_2.m) \frac{W+w_1}{W+w_2}$ are the volumes of equal

$\cdot v_2 + x_2.m)(W+ w_1)$
$\cdot v_1 + x_1.m)(W + w_2)$.

Fig. 563.



structed in which weights might be d, so that the volume of the lower e altered. The above formula would v_2. A hydrometer of this kind, to 2·0, was shown in the Exhibi-3.)
ly employed on the Continent, and n his *Élémens de Pharmacie*, p. 466. onstructed for liquids heavier and bvious that this is not necessary. ie graduation is as on the right-mined by marking as 0 the point pure water, and as 15 the point to ts. by weight of salt in 85 pts. of to 15 equal parts, and a scale of r as desirable.
e graduation is as on the left-hand w determined by pure water, while the hydrometer sinks in a solution er. The interval is divided into nded as in the former case.
eters being entirely arbitrary, the ertain from their indications the specific gravities ie standard:

é's *Hydrometer with the real Specific Gravities ds heavier than water.*

Specific gravity.	Degrees.	Specific gravity.	Degrees.	Specific gravity.
1·152	39	1·345	58	1·617
1·160	40	1·357	59	1·634
1·169	41	1·369	60	1·652
1·178	42	1·382	61	1·670
1·188	43	1·395	62	1·689
1·197	44	1·407	63	1·708
1·206	45	1·421	64	1·727
1·216	46	1·434	65	1·747
1·226	47	1·448	66	1·767
1·236	48	1·462	67	1·788
1·246	49	1·476	68	1·809
1·256	50	1·490	69	1·831
1·267	51	1·505	70	1·854
1·277	52	1·520	71	1·877
1·288	53	1·535	72	1·900
1·299	54	1·551	73	1·924
1·310	55	1·567	74	1·949
1·322	56	1·583	75	1·974
1·333	57	1·600	76	2·000

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Baumé's *Hydrometer for liquids lighter than water.*

Degrees.	Specific gravity.	Degrees.	Specific gravity.	Degrees.	Specific gravity.	Degrees.	Specific gravity.
10	1·000	23	·918	36	·849	49	·789
11	0·993	24	·913	37	·844	50	·785
12	·986	25	·907	38	·839	51	·781
13	·980	26	·901	39	·834	52	·777
14	·973	27	·896	40	·830	53	·773
15	·967	28	·890	41	·825	54	·768
16	·960	29	·885	42	·820	55	·764
17	·954	30	·880	43	·816	56	·760
18	·948	31	·874	44	·811	57	·757
19	·942	32	·869	45	·807	58	·753
20	·936	33	·864	46	·802	59	·749
21	·930	34	·859	47	·798	60	·745
22	·924	35	·854	48	·794		

Cartier's *Hydrometer* is sometimes used on the Continent. The degree of its scale 22 coincides with the degree 22 of Baumé, but above and below this point, the degrees of Baumé are diminished in the ratio of 16 to 15. This hydrometer is only constructed for liquids lighter than water, and any who may require it can easily reduce its readings to those of Baumé, and make use of the table already given for Baumé's hydrometer.

Beck's *Hydrometer* has a scale of which 0 corresponds to the specific gravity 1·00, and 30 to that of ·850, and the scale is extended in equal parts above or below 0, as far as desirable. The following tables are necessary:

Table for converting degrees of Beck's *Hydrometer into real Specific Gravities.*

Degrees.	Specific gravity.		Degrees.	Specific gravity.		Degrees.	Specific gravity.	
	Greater than 1·000.	Less than 1·000.		Greater than 1·000.	Less than 1·000.		Greater than 1·000.	Less than 1·000.
1	1·006	·994	25	1·172	·872	48	1·393	·780
2	1·012	·988	26	1·181	·867	49	1·405	·776
3	1·018	·983	27	1·189	·863	50	1·417	·773
4	1·024	·977	28	1·197	·859	51	1·429	·769
5	1·030	·971	29	1·206	·854	52	1·441	·766
6	1·037	·966	30	1·214	·850	53	1·453	·762
7	1·043	·960	31	1·223	·846	54	1·466	·759
8	1·049	·955	32	1·232	·842	55	1·478	·756
9	1·056	·950	33	1·241	·837	56	1·491	·752
10	1·063	·944	34	1·250	·833	57	1·504	·749
11	1·069	·939	35	1·259	·829	58	1·518	·746
12	1·076	·934	36	1·268	·825	59	1·532	·742
13	1·083	·929	37	1·278	·821	60	1·546	·739
14	1·090	·924	38	1·288	·817	61	1·560	·736
15	1·097	·919	39	1·298	·813	62	1·574	·733
16	1·104	·914	40	1·308	·810	63	1·589	·730
17	1·111	·909	41	1·318	·806	64	1·604	·727
18	1·118	·904	42	1·328	·802	65	1·619	·723
19	1·126	·899	43	1·339	·798	66	1·635	·720
20	1·133	·895	44	1·349	·794	67	1·651	·717
21	1·141	·890	45	1·360	·791	68	1·667	·714
22	1·149	·885	46	1·371	·787	69	1·683	·711
23	1·157	·881	47	1·382	·783	70	1·700	·708
24	1·164	·876						

Twaddell's *Hydrometer* is often used in England for testing liquids denser than water. It is graduated in such a manner that the reading, or number of degrees, multiplied by 5 and added to 1000, gives the specific gravity with reference to water as 1000. Thus,

10° Twaddell indicates the specific gravity 1050 or 1·050,
90° " " 1450 or 1·450.

(E. Dingler, Polytech. Jour. lxii. 329.)

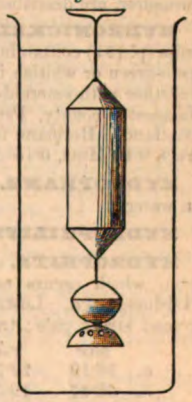
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strument with a large bulb and very narrow stem,
avity of water from various springs or other
raulique, tom. i. § 614–627.)
to taking the specific gravity of sea-water. In
nt of this kind made of gilt brass, the flat stem
n 3 or more points experimentally determined.
he third place of decimals; thus the degree 27
nd the whole range of the instrument is accord-

ument to the navy and mercantile shipping are
ccuracy is secured by comparison and determi-
e case of barometers and thermometers. They
ations on the water of the ocean.
y resembling Sykes' hydrometer, but adapted by
quality of milk. By means of a series of eight
grees, and a thermometer and an ivory sliding-
er that the milk may be tested at any tempe-
tandard temperature of 55° without calculation
Agric. Survey of Lancashire). This instrument
tometer first described by Sir Joseph Banks
consisting of a simple graduated test-tube, in
d, until the cream rises to the top and its pro-
ured off.
f little balloon-shaped glass bubbles, adjusted to
nen a number of them are thrown into a liquid,
ity than the liquid sink into it, those which are
the single bead which corresponds in specific
ferently in any part of the liquid, or at least
h bead is engraved the specific gravity which
uments were much improved and patented by

omewhat from and is even simpler than the com-
has only a single mark on the stem, but at the
which weights are to be
the mark in the liquid
we measure the weight
ced: for this weight, by
to the whole weight of
he liquid. Hence the
quid to the weight for
vity required.
e accurate results than
nconvenient in common

Fig. 564.



invented by the author
genious modification of
rendered capable of de-
ies as well as of liquids.
bears three scale-pans,
ve the surface of the
hich is concave down-
e instrument. When
allowed to escape from

quids, this hydrometer is identical with that of
nent is generally adjusted from the first so that
will cause it to sink in pure water, at 62° F., up
ight, however, required for this purpose, what-
the weight of the instrument itself being W.
pecific gravity differs from that of water, and is
or greater than w must be placed in the upper
nen $\frac{W+w_2}{W+w_1}$ is obviously the specific gravity

olid substance, a portion of it weighing less than
ich additional weight, say w_3, that the hydro-
he zero mark, as it does when loaded with w_1.

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Then the weight of the substance is obviously $w_1 - w_3$. Now transfer the subst to one of the lower pans, that which is concave downwards being used when substance is lighter than water, and has to be forced under. The instrument again be adjusted so as to float in water at the usual level, and it will be found some further weight has to be added for this purpose. Let the weight now in pans be w_4. Then the specific gravity of the substance is $\frac{w_1 - w_3}{w_4 - w_3}$.

This instrument becomes more and more delicate and accurate in its indication the stem is of smaller diameter. As actually constructed by the inventor, the s was a piece of hardened steel wire $\frac{1}{20}$ inch in diameter. But the more delicate, more troublesome does the instrument become in use; the adherence of water to parts above the surface, the adherence of air to those below, and the inevitable cha of temperature in the water, are sources of unavoidable error. The chemist, in balance and specific gravity bottle, has always at hand the means of ascertai specific gravities with any degree of accuracy, and is not likely to use Nichols hydrometer. But this instrument is a valuable companion to the scientific trave since, besides its use in taking specific gravities, it may be employed in place balance for ascertaining any small weight.

Having now given all that it is likely to be practically useful concerning hydrometer, we think it quite needless to describe all the minute varieties of const tion and arbitrary scales proposed by Homberg, Clarke, Gay-Lussac, Dica, Riel Adie, Quin, Guyton, Speers, Charles, and others. Much information is given in *Handwörterbuch der Chemie*, 2te Aufl., &c., ii. 165–190.

The hydrometer is said to have been first invented by Hypatia, daughter of T Alexandrinus, who flourished about the end of the fourth century, but the disco is sometimes ascribed to Archimedes. However this may be, the English philoso Robert Boyle appears to have first brought it into use, having described it in Trans. for 1675 (x. 329), or *Boyle's works* (1772, iv. 204). His instrument was al identical with Nicholson's hydrometer, and was especially intended to determine fineness of gold alloys, being hence called a "*New Essay Instrument*."

Many references concerning the history and varieties of the hydrometer wil found in *Young's Lectures* [1845] i. 240.—*Bénoit's Théorie Générale des Pèse-liqu* [1821], is a work we have not been able to meet with. Clarke's hydrometer (Trans. xxxvi. [1730], p. 277), Brewster's Capillary Hydrometer, Staktometer, or I measurer, are described in the Edinburgh Cyclopædia, xi. pt. ii. p. 442.—W. S. J.

HYDRONICKELMAGNESITE, also called *Pennite*. A variety of hydro mite (p. 191) containing 2 per cent. or less of carbonate of nickel, with water. It f pale-green or whitish incrustations, having a surface of minute spherules, and o together with emerald-nickel, into which it graduates, also with chromic iron, at T Lancaster county, Pennsylvania, and according to Heddle, at Swinaness, in U Shetland. Hermann found in it 44·54 CO^2, 20·10 CaO, 27·02 MgO, 1·25 Na^2O, FeO, 0·40 MnO, 0·15 Al^2O^3, and 5·84 H^2O = 100. (Dana, ii. 457.)

HYDROPHANE. A variety of opal, which becomes transparent when imm in water.

HYDROPHILITE. A name applied to chloride of calcium.

HYDROPHITE, also called *Jenkinsite*. A hydrated silicate of magnesium iron, which occurs massive, and sometimes fibrous. Specific gravity 2·46— Hardness = 3·5. Lustre, feeble, subvitreous. Colour, mountain-green to blac green: streak pale; translucent to opaque.

	SiO^2	FeO	MnO	MgO	Al^2O^3	V^2O^3	H^2O	
a.	36·19	22·73	1·66	21·08	2·895	0·125	16·08	= 100·75
b.	38·97	19·30	4·36	22·87	0·53	. .	13·36	= 99·38
c.	37·42	20·60	4·05	22·75	0·98	. .	13·46	= 99·28

a. Hydrophite from Taberg, in Sweden (Svanberg, Pogg. Ann. li. 535).—*b. kinsite* from O'Neil's mine, Orange county, New York (Smith and Brush, Sill. J. ii. 369). These analyses lead to the formula $\left.\begin{matrix}\frac{3}{5}MgO\\ \frac{2}{5}FeO\end{matrix}\right\}$ $^4.3SiO^2.3H^2O$; which, regar 2 at. water as basic, may be reduced to the form of an orthosilicate, $3(2M^2O.SiO^2).$ or $3M^4SiO^4.H^2O$.

HYDROPITE. A silicate of manganese with excess of manganous o containing, according to Du Menil's analysis, 54·37 per cent. SiO^2, 41·33 MnO, FeO, and 1·25 CaO. (*Rammelsberg's Mineralchemie*, p. 459.)

HYDROPSIN. The name given by Garnal (Schmidt's Jahrb. d. ges. cvi. 8) to an albuminous substance which he obtained from a dropsical effusion.

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HYDROQUINONE. *Hydrochinone, Hydrokinone* (Wöhler, Ann. Ch. Pharm. xlv. 354; li. 150; Hesse, *ibid.* cx. 194; cxiv. 292).—This name is applied to two substances, one colourless and the other green.

COLOURLESS HYDROQUINONE (*Pyroquinole*), $C^6H^6O^2$, isomeric with oxyphenic acid, is the chief product of the dry distillation of quinic, carbohydroquinonic, and oxysalicylic acids (*q. v.*), and is likewise produced by the action of reducing agents (stannous chloride or sulphurous acid) on quinone, from which it differs by 2 at. H; also, together with a brown crystalline body containing $C^{18}H^{14}N^2O^2$, by the action of phenylamine on quinone (A. W. Hofmann, Proc. Roy. Soc. xiii. 4):

$$\underset{\text{Phenylamine.}}{2C^6H^7N} + \underset{\text{Quinone.}}{3C^6H^4O^2} = \underset{\text{Brown crystals.}}{C^{18}H^{14}N^2O^2} + \underset{\text{Hydroquinone.}}{2C^6H^6O^2}.$$

Preparation.—1. The distillate, mixed with solid particles, which is obtained by the dry distillation of quinic acid, is filtered from tar, and again, after cooling, to separate benzoic acid; the yellow, heavy, oily mixture of benzene, phenic acid and salicylous acid, is distilled from the filtrate; the brown residue in the retort is evaporated and left to cool till benzoic acid crystallises out; the mother-liquor is diluted with water, which makes the liquid milky and separates tar; and the resulting filtrate is evaporated till the hydroquinone crystallises out.—2. Sulphurous acid gas is passed through warm water saturated with quinone, and having quinone also suspended in it, till all the quinone is dissolved, and the liquid appears colourless; the solution is then gently evaporated to the crystallising point, and the crystals are purified by pressure and recrystallisation.—It is not necessary previously to remove the sulphuric acid by carbonate of barium.—A saturated aqueous solution of quinone may also be mixed with aqueous hydriodic acid, and the watery liquid, after filtration from the iodine, evaporated to the crystallising point.

Properties.—Hydroquinone forms transparent, colourless, rhombic crystals exhibiting the combination, $\infty\breve{P}\infty$. $\infty P\infty$. P. oP (Hesse). It sublimes, when heated, in shining laminæ, like benzoic acid; melts at 177·5° and solidifies to a crystalline mass at 163°. It is inodorous, has a sweetish taste, and is neutral to vegetable colours. It dissolves easily in *water*, especially when hot, also in *alcohol* and in *ether*. From solutions of *alkaline sulphites*, it crystallises unaltered, sometimes however in sulphur-yellow rhombohedrons or long four-sided prisms, resembling the sulphydrates of hydroquinone. (Hesse.)

Decompositions.—1. Hydroquinone, suddenly heated above the boiling point, is partially decomposed into quinone and green hydroquinone. When passed in the state of vapour through a glass tube at a low red heat, it is resolved into quinone and hydrogen (Hesse).—2. *Oxidising agents*, viz. chlorine, chromate of potassium, sesquichloride of iron, or nitrate of silver, convert hydroquinone dissolved in water into green hydroquinone, with formation of hydrochloric acid, chromic oxide, or protochloride of iron and hydrochloric acid, or with precipitation of silver.—3. Strong *nitric acid* converts it almost wholly into oxalic acid (Hesse).—With *hydrochloric acid and chlorate of potassium* it yields tetrachlorquinone (chloranil) (Hesse).—4. The aqueous solution of hydroquinone imparts a saffron-yellow colour to *cupric acetate*, and when heated throws down cuprous oxide, quinone volatilising at the same time.—5. *Ammonia* imparts to it a brown-red colour, and yields on evaporation a brown mass like ulmic acid. *Potash* acts in like manner. (Wöhler.)

Hydroquinone dissolves in a moderately concentrated hot solution of neutral *acetate of lead*, and the solution, on cooling, yields prisms containing $C^6H^6O^2.C^4H^6PbO^4 + \frac{2}{3}H^2O$. These crystals give off 5·23 per cent. of water (nearly $\frac{2}{3}$ at.) over sulphuric acid.

Sulphydrates of Hydroquinone.—There are two of these salts. The first, containing $4C^6H^6O^2.H^2S$, is obtained in colourless prisms by passing sulphydric acid gas into a saturated solution of hydroquinone heated to 40°.—The second $3C^6H^6O^2.H^2S$, is obtained, by passing sulphydric acid into a cold saturated solution of hydroquinone, in small shining crystals, which redissolve when heated if the passage of the gas be continued, the solution, as it cools, yielding the compound in very regular colourless rhombohedrons. These crystals remain unaltered when dry, but water eliminates sulphydric acid from them, and on boiling the solution, hydroquinone is reproduced.

GREEN HYDROQUINONE OR QUINHYDRONE. $C^{12}H^8O^4 = C^6H^6O^2.C^6H^4O^2$.—This compound may be regarded either as a compound of quinone and colourless hydroquinone, or as a double molecule of the latter compound *minus* 2 at. H, or again as a double molecule of quinone ($C^{12}H^8O^4$) *plus* 2 at. H.

It is produced:—1. By mixing the aqueous solutions of quinone and hydroquinone, whereupon it is immediately precipitated in the crystalline form.—2. By combining aqueous quinone with a quantity of hydrogen not sufficient for the formation of colourless hydroquinone; *e. g.* aqueous quinone mixed with sulphuric acid at the

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negative pole of the galvanic circuit; quinone mixed with sulphuric acid in co with zinc; aqueous solution of quinone with gradual addition of dichloride of ti protosulphate of iron, or sulphurous acid, or alloxantin, the latter being converted alloxan.—3. By the partial dehydrogenation of aqueous hydroquinone; *e.g.* spongy platinum or animal charcoal moistened with the solution is exposed to the when chlorine gas is passed through aqueous hydroquinone, or that liquid is mixed nitric acid, chromate of potassium, sesquichloride of iron, or nitrate of silver.— mixtures prepared according to (2) or (3) with concentrated solutions, assume while a black-red colour, and then become filled with long, green, metallic-looking pr of quinhydrone; but if the solutions are too dilute, the quinhydrone remains disso and is decomposed, emitting the odour of quinone.—The largest crystals are obta by at once adding to a saturated aqueous solution of quinone (or even to its mother-liq a quantity of aqueous sulphurous acid just half sufficient for the formation of hy quinone.

Properties.—Quinhydrone forms very long and thin green prisms, having a met lustre, like the wings of gold-beetles or humming birds, and brighter even murexid; they appear red-brown by transmitted light when strongly magnified. melts easily to a brown liquid, and sublimes partly undecomposed in green lam Smells slightly like quinone, and has a pungent taste.

It dissolves sparingly in cold *water*, abundantly and with red-brown colour in water, separating as it cools. *Alcohol* and *ether* dissolve it readily, forming yello red solutions. *Ammonia* dissolves it with green colour. The aqueous solution f with *acetate of lead* a bright greenish-yellow precipitate, quickly changing to grey.

Decompositions.—1. When quinhydrone is heated, it sublimes partly undecomp partly converted into yellow quinone.—2. When it is boiled with water, quinone di over, and the remaining dark red-brown liquid contains, together with a large qua of hydroquinone, a brown tar, which separates partly on cooling, partly on subseq addition of water.—3. The green solution of quinhydrone in *ammonia* quickly ass a dark red-brown colour on exposure to the air, and leaves a brown amorphous when evaporated.—4. Quinhydrone is converted into colourless hydroquinon aqueous *sulphurous acid*, *stannous chloride*, or *zinc and sulphuric acid*, but no hydriodic acid or tellurhydric acid.—5. The aqueous solution quickly reduces *ni of silver*, on addition of ammonia.

Derivatives of Hydroquinone.

Carbohydroquinonic acid. $C^7H^6O^4 = C^6H^6O^2.CO^2 = \left.\begin{matrix}(C^7H^5O)'''\\ H^3\end{matrix}\right\}O^3$. (O. He Ann. Ch. Pharm. cxii. 527, cxiv. 292; cxxii. 22; E. Lautemann, *ibid.* cxx. 31 An acid produced:—1. By the action of bromine on aqueous quinic acid.—2. By ing quinic acid to above 200°.—3. Small quantities of it are likewise obtained by action of chlorate of potassium and hydrochloric acid on dilute aqueous quinic or of peroxide of manganese and sulphuric acid on aqueous quinate of calcium. (Hes

Preparation.—Bromine is added to aqueous quinic acid by portions of 10 drops till a portion of it remains undissolved, even after the liquid has been freque agitated and left to stand for 12 hours. The solution is then decanted from the dissolved bromine, diluted, filtered, and mixed with carbonate of lead, as long brisk evolution of gas is thereby set up, and bromide of lead produced. The filt evaporated to a thick syrup on the water-bath, and shaken up with about 5 vol. et yields to this liquid carbohydroquinonic acid, which after the ether has been dist off, remains as a brown crystalline residue. It is purified by re-crystallisation water containing hydrochloric acid, with help of animal charcoal.—Or the solu treated with bromine and filtered, is mixed with carbonate of lead, till this salt be to take up organic substances; the filtrate is precipitated with solution of neu acetate of lead, and then, after this precipitate has been collected, a further precipi is obtained by addition of ammonia. By decomposing the precipitates suspende water with sulphydric acid, then boiling up and diluting the filtrate, carbohy quinonic acid is obtained from the first precipitate. The acid obtained from the sec lead-precipitate still retains unaltered quinic acid, from which it may be separ by ether. (Hesse.)

Properties.—Carbohydroquinonic acid crystallises from its aqueous solution 1 at. water ($C^7H^6O^4.H^2O$), in furcate groups of needles, also in rhombic lamina granular crystals. It is dimorphous. The granular crystals are distorted tw belonging to the monoclinic system. The needles are rhombic prisms, having acute edges perpendicularly truncated, cleavable at right angles to the prismatic f (Hesse).—The crystallised acid dissolves in 40 or 50 pts. of *water* at 17°, very ea

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in boiling water and in *alcohol*, but is insoluble in *ether*. It has a sour and bitter taste and reddens litmus. Heated to 100° it gives off, on the average, 10·5 per cent. water, leaving the anhydrous acid, $C^7H^6O^4$, which melts at 207° (corrected) with partial decomposition, and solidifies in the radio-crystalline form between 160° and 170° (Hesse). When cautiously heated, it sublimes with partial decomposition. (Lautemann.)

Decompositions.—1. Carbohydroquinonic acid is resolved by fusion, and with great facility when heated to 240°, into carbonic anhydride and hydroquinone, $C^7H^6O^4 = C^6H^6O^2 + CO^2$ (Hesse). When it is heated with pumice, pyrocatechin is obtained instead of hydroquinone, the former being apparently capable of passing, under circumstances not exactly known, into hydroquinone (Lautemann).—2. It is not altered by boiling dilute *nitric acid*; the concentrated acid converts it, with rise of temperature and evolution of nitrous acid, into oxalic acid, together with a trace of a yellow substance.—3. *Sulphuric anhydride* dissolves it, without evolution of gas, forming a blue liquid, brownish by reflected light. No conjugated sulphuric acid can be obtained from this solution.—In *oil of vitriol*, carbohydroquinonic acid dissolves slowly, and chars when heated.—4. *Bromine* dissolves slowly in the aqueous acid, with evolution of gas.—5. Aqueous carbohydroquinonic acid, in contact with *acid carbonate of calcium* and air, acquires a dark, nearly black colour, and deposits a black precipitate, which effervesces with acids (Hesse).—6. From *cupric hydrate* and *potassio-cupric tartrate* aqueous carbohydroquinonic acid separates cuprous oxide; from *mercuric* and *silver-salts* it separates the metal. Dilute aqueous carbohydroquinonic acid, mixed at 8° or 10° with neutral solution of *nitrate of silver*, becomes dark-coloured in a quarter of an hour, even in the dark, and in three hours separates metallic silver (Hesse). According to Lautemann it reduces nitrate of silver when heated, but not in the cold.

The carbohydroquinonates are, for the most part, easily soluble in water, sparingly soluble or insoluble in alcohol. Hesse regards the acid as monobasic, and the ammonium-salt as a basic salt, in which 1 at. ammonia takes the place of water of crystallisation, $C^7H^5(NH^4)O^4.NH^3$. The formula $\left.\begin{matrix}(C^7H^5O)'''\\H^3\end{matrix}\right\}O^3$ represents it as triatomic but monobasic, like glyceric acid (ii. 875). Strecker (*Handwörterb.* ii. [2], 996), regards the acid as dibasic. Carbohydroquinonic acid decomposes the carbonates of the alkaline earths. Its salts turn brown in the air. In contact with a small quantity of sesquichloride of iron, they acquire a violet colour; with a larger quantity, a fine purple-violet to chrome-green colour especially in neutral solution. (Hesse.)

Ammonium-salts.—When dry ammonia-gas is passed over dry carbohydroquinonic acid, 100 pts. of the acid take up from 22·3 to 22·7 pts. of ammonia (2 at. = 22·08 NH^3), without giving off water. The resulting compound, freed from excess of ammonia by standing over oil of vitriol, contains 44·7 per cent. C, and 6·2 H, corresponding to the formula, $C^7H^5(NH^4)O^4.NH^3$ (calc. 44·68 per cent. C, and 6·38 H). When exposed to moist air, it quickly gives off ammonia, and dissolves, with alkaline reaction, in water and alcohol. The latter solution, when evaporated, deposits small acid crystals. Hydrated ether partially dissolves the ammonium-salt, leaving a portion, perhaps consisting of $C^7H^5(NH^4)O^4.H^2O$. An ether-alcoholic solution of carbohydroquinonic acid becomes turbid when ammonia gas is passed over it, and then clear, depositing concentric groups of prisms. Brown substances are formed at the same time. (Hesse.)

Lead-salt.—From aqueous carbohydroquinonic acid, an aqueous or alcoholic solution of neutral acetate of lead throws down an amorphous yellow precipitate, easily soluble in nitric acid, with difficulty in acetic acid. Part of the carbohydroquinonic acid dissolves at the same time in the acetic acid which is set free, so that the filtrate still gives a precipitate with ammonia. (Hesse.)

The *potassium-salt* is precipitated from its aqueous solution by alcohol in the form of a syrup.—The *manganous salt* forms small prisms, easily soluble in water.—The *zinc-salt* forms laminæ.—Aqueous carbohydroquinonic acid yields a greyish-yellow precipitate with *tartar emetic*; and with *ferric hydrochlorate*, a dark green solution changing to violet on addition of acid carbonate of sodium, or of tartaric acid, ferric hydrochlorate, and ammonia. It does not precipitate *gelatin*.

The following acids give reactions very similar to those of carbohydroquinonic acid: 1. *Morintannic acid* and *Morin*, which, according to Hlasiwetz, are isomeric with carbohydroquinonic acid.—2. *Deuterocatechuic acid*, $C^6H^6O^4$, and *Tricatechuic acid*, $C^7H^{10}O^4$. These two acids are supposed by Strecker (Ann. Ch. Pharm. cxviii. 280) to exist in catechu, inasmuch as he regarded the pyrocatechin, first as the one, then as the other of these acids, and finally, as a mixture of the two.—3. *Protocatechuic acid.* This acid, according to Lautemann (Ann. Ch. Pharm. cxx. 315), must be regarded as identical with carbohydroquinonic acid, since the latter acid, when

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heated with pumice, is capable of yielding pyrocatechin. But according to Hesse (Ann. Ch. Pharm. cxxii. 221), the two acids react differently with cupric tartrate, and must therefore be regarded as only isomeric.—4. *Oxysalicylic acid.* With regard to this acid, Lautemann thinks it probable that it may be capable of passing into carbohydroquinonic acid (or the latter into oxysalicylic acid).—5. *Hypogallic acid.*

Ethyl-carbohydroquinonic acid, $C^9H^{10}O^4 = \left.\begin{matrix}(C^7H^3O)'''\\H^2.C^2H^5\end{matrix}\right\}O^3$. *Carbohydroquinonic ether.*—To prepare this compound, carbohydroquinonic acid is dissolved in alcohol of 90 per cent.; the solution is saturated with hydrochloric acid gas; the alcohol is distilled off in the water-bath; the residue is shaken up with ether, as long as that liquid takes up a substance which colours ferric chloride; the ether is then distilled off; the brown crystalline residue is shaken up with boiling, very dilute alcohol, and a small quantity of carbonate of sodium; the solution is left to cool; and the acid is again exhausted with ether. The ethereal solution when evaporated leaves coloured crystals, which may be decolorised by again treating them with dilute alcohol, soda, and ether. It forms colourless prisms united in radiate groups, neutral, melting at 134° (corrected), and becoming crystalline again at 124·3°.

The ether melts in boiling water before dissolving; dissolves easily in *alcohol*, and especially in common *ether*. The aqueous solution, added to *neutral acetate of lead*, forms a white amorphous precipitate soluble in acetic acid; it colours *ferric hydrochlorate* violet, changing to purple-violet on addition of a larger quantity of the iron-salt, and finally to chrome-green. It reduces *mercuric chloride, nitrate of silver*, and *potassio-cupric tartrate.* (Hesse, *loc. cit.*)

Chlorinated Hydroquinones. (Wöhler, Ann. Ch. Pharm. li. 155.—Städeler, *ibid.* lxix. 132, 306, 321.)—These compounds are produced by the action of reducing agents on the corresponding chlorinated derivatives of quinone: they are most easily prepared by means of sulphurous acid. They bear a greater resemblance to hydroquinone in proportion as they contain less chlorine. They act like weak acids, their alcoholic solutions yielding white precipitates with acetate of lead, the quantity of the precipitate being increased by addition of ammonia. The chlorine in these compounds does not exhibit its usual reaction with nitrate of silver. By oxidising agents, viz. by nitric acid and sesquichloride of iron, they are converted either into the corresponding chlorinated quinones, or compounds of these with the chlorinated hydroquinones.

Monochlorinated Hydroquinone, $C^6H^5ClO^2$, forms tufts of colourless prisms, very soluble in water, alcohol and ether, and liquefying in contact with the vapour of ether. It melts easily, and sublimes in white laminæ, with partial decomposition. Its aqueous solution reduces nitrate of silver. It dissolves in ammonia, forming a dark-blue solution, changing to green, yellow, and red-brown.

Dichlorinated Hydroquinone, $C^6H^4Cl^2O^2$, forms beautiful nacreous crystals, which melt at 164°, and begin to sublime at 120°. It reddens litmus; dissolves sparingly in cold water, easily in boiling water, also in alcohol, in ether, and in hot acetic acid; sparingly in boiling hydrochloric acid; it is soluble also in hot concentrated sulphuric acid, and separates on cooling. With dilute potash it forms a colourless solution, which on exposure to the air turns green, then red, and deposits a violet powder. With ammonia, it forms a yellow solution, which reddens in contact with the air, and deposits a brownish precipitate.

Trichlorinated Hydroquinone, $C^6H^3Cl^3O^2$, forms colourless laminæ, or flattened prisms melting at a little above 130°, and subliming in iridescent scales. It dissolves readily in alcohol and in ether; the alcoholic solution reddens litmus. It dissolves in potash and in ammonia, forming green solutions, which turn first red, then brown, and yield copious precipitates with hydrochloric acid.

Tetrachlorinated Hydroquinone, $C^6H^2Cl^4O^2$, forms colourless, nacreous laminæ, insoluble in water, very soluble in alcohol and ether; its solutions redden litmus. When heated, it begins to turn brown at 160°, the colour becoming stronger towards 220°; it then sublimes rapidly, but does not melt till more strongly heated; the melted mass crystallises on cooling. It dissolves in potash and in ammonia. The potash solution, saturated hot, deposits on cooling, prismatic crystals, apparently consisting of a potassium-salt.

Octochlorinated Acetyl-dihydroquinone, $C^{14}H^6Cl^8O^5 = C^{12}H^3(C^2H^3O)Cl^8O^4$ (Hesse, Ann. Ch. Pharm. cxiv. 292).—Produced by passing sulphurous anhydride into a mixture of tetrachloroquinone and glacial acetic acid, then evaporating and subliming:

$$2C^6Cl^4O^2 + C^2H^4O^2 + H^2O + 2SO^2 = C^{14}H^6Cl^8O^5 + 2SO^3.$$

It forms colourless laminæ, which melt at 230°, dissolve easily in ether, alcohol, hot benzene, and strong acetic acid, but are nearly insoluble in water.

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droquinone, $C^{14}H^8Cl^8O^4 = C^{12}H^3(C^2H^5)Cl^8O^4$
ng sulphurous anhydride for some time through a
ith 20 pts. alcohol of 92 per cent. The tetrachloro-
mixed with water yields the octochlorinated ethyl-
benzene in colourless rhombic laminæ, often an
ion $\infty\breve{P}\infty$. ∞P . $m\breve{P}\infty$. The compound melts at
°; is nearly insoluble in water and in solutions of
hol, ether, hot benzene, and acetic acid. The
mes acid and brown-coloured, and ultimately
c lustre; on addition of hypochlorite of sodium,
then tetrachloroquinone. Octochlorinated ethyl-
, and moistened with a few drops of water,

The chlorinated hydroquinones combine with the
unds which may be regarded as chlorinated
ounds are produced by mixing the aqueous
he action of oxidising agents on the chlorinated
n the chlorinated quinones. The *dichlorinated*
mes in brown needles, which colour the skin
chlorinated compound, $C^6H^4Cl^2O^2.C^6H^2Cl^2O^2$, in
crystals; in the hydrated state, with $2H^2O$,
inated compound, $C^6H^3Cl^3O^2.C^6HCl^3O^2$, appears
inone with a quantity of sulphurous acid not
trichlorinated hydroquinone; and the *octochlo-*
by the action of nitrate of silver on perchlorinated

$C^6H^7PO^5 = C^6H^6O^2.PHO^3$ (Hesse, Ann. Ch.
ves in cold dilute aqueous phosphoric acid with-
the solution, a copious evolution of gas takes
ion, and the remaining brown solution contains
parates partly crystalline, partly amorphous, has
ation of the acid is represented by the equation:

$$= \underset{\text{Phosphohydro-quinonic acid.}}{C^6H^7PO^5} + CO + 4H^2O.$$

$^{18}H^{18}SO^8 = 3C^6H^6O^2.SO^2$ (A. Clemm, Ann. Ch.
s anhydride is passed through a solution of
ely converted into colourless hydroquinone, and
r continued, the liquid again turns yellow, and
nombohedral crystals having the above composi-
ecomposible, and gives off sulphurous anhydride
quinone.

Acids containing the elements of hydroquinone
y the action of sulphuric acid or anhydride on
esse, Ann. Ch. Pharm. cx. 194; cxiv. 292.)

id, $C^6H^6S^2O^8 = C^6H^6O^2.2SO^3$.—*Preparation of*
acid is poured into fused or finely pulverised
onger causes any considerable evolution of gas;
e end of the operation, diluted after cooling with
with carbonate of barium, and evaporated to the
ich first separate take up a large quantity of
quor yields a less coloured salt.
nposing the barium-salt with the exactly equiva-
e lead-salt with sulphydric acid, forms an acid
ble in *ether*.
netallic salts have been obtained. The salts and
ydrochlorate a fine blue colour, which disappears
ngy tint on cooling. The blue colour is also
by addition of nitric or acetic acid, quickly by
r tartaric acid. A similar action is exerted by
ride of calcium, sulphate of magnesium, phosphate
ferric hydrochlorate. The salts separate metallic

decomposing the barium-salt with carbonate of
ated solution in large crystals.

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The *barium-salt*, $C^6H^4Ba''S^2O^8.4H^2O$, forms beautiful monoclinic prisms, with gles of 113° 4′. When heated, it gives off suffocating vapours, hydroquinone, nhydrone, and water, leaving a residue of charcoal. The salt dried in the air, or r oil of vitriol, gives off at 90° from 10·8 to 11·5 per cent. water (3 at. = 11·31 per t. H^2O), then between 120° and 160° an additional 3·3 per cent. (1 at. = 3·77 per t. H^2O), corresponding in all to 4 at. The salt dissolves readily in boiling water, with ficulty in cold water, and in alcohol either cold or boiling, but is insoluble in ether.

The *calcium-salt* resembles the barium-salt.

The *lead-salt*, $C^6H^4Pb''S^2O^8.Pb''H^2O^2$, is separated from the concentrated solution of barium-salt by neutral acetate of lead, as a bulky precipitate, which quickly changes o yellowish microscopic crystals having a silky lustre. When heated, it assumes a non-yellow colour, and becomes carbonised. It is nearly insoluble in water and tic acid, easily soluble in nitric acid, precipitable by ammonia.

The *potassium-salt*, $2C^6H^4K^2S^2O^8.3H^2O$, is obtained by neutralising the aqueous d with carbonate of potassium, and separates with the same composition, even from utions containing 2 at. acid to 1 at. potash. It forms colourless prisms having a ine taste, easily soluble in water, sparingly in alcohol. They retain 6·9 per cent. ter over oil of vitriol, give off the whole at 150°, and decompose when melted.

2. *Sulphodihydroquinonic acid*, $C^{12}H^{16}SO^9 = 2C^6H^6O^2.SO^3.2H^2O$.—Produced the action of fuming sulphuric acid on hydroquinone. The solution, which is formed thout evolution of gas, yields, when saturated with carbonate of barium, a barium- t, which crystallises in concentrically grouped needles containing $C^{24}H^{30}Ba''S^2O^{18}$. is salt is easily soluble in water and in aqueous alcohol, sparingly soluble in abso- e alcohol, and is precipitated therefrom in flocks by ether.

3. *Disulphodihydroquinonic acid*, $C^{12}H^{14}S^2O^{11} = 2C^6H^6O^3.2SO^3.H^2O$.—Hydro- none exposed to the vapour of sulphuric anhydride deliquesces and yields this acid. e *potassium-salt*, $C^{12}H^{12}KS^2O^{11}$, crystallises in colourless monoclinic prisms or in ttened, sharp-pointed needles, easily soluble in water and in hot alcohol. The solu- n treated with ferric hydrochlorate acquires a transient dark-blue colour; it forms a ite precipitate with ammoniacal acetate of lead, and reduces silver from the nitrate.

HYDROSALICYLAMIDE. $C^{21}H^{15}N^2O^3 = N^2(C^7H^6O)^3$. *Salhydramide. Salicylide. Hydride of Azosalicyl* (Ettling, Ann. Ch. Pharm. xxxv. 261).—This compound roduced by the action of ammonia on hydride of salicyl (salicylous acid):

$$3C^7H^6O^2 + 2NH^3 = C^{21}H^{15}N^2O^3 + 3H^2O.$$

e hydride of salicyl is dissolved in 3 or 4 times its volume of cold alcohol, and a ntity of ammonia is added equal to that of the hydride of salicyl employed. The ution then immediately yields yellowish-white needles, and soon solidifies in a mass. applying a gentle heat, the product dissolves completely, and the liquid, on cooling, posits crystals of hydrosalicylamide.

Hydrosalicylamide crystallises in triclinic prisms, without modification. Angle P : $\infty P'$ = 117° 30′; oP : $\infty'P$ = 103° 30′; oP : $\infty P'$ = 93° 30′. It appears to insoluble in *water*, and dissolves but sparingly in cold *alcohol*, but quickly in about pts. of boiling alcohol. At 300° it melts to a yellow and brownish mass, yielding white, very light sublimate. At a higher temperature it carbonises. It is not omposed by weak *potash-ley* in the cold, but on boiling it gives off ammonia and ns salicylide of potassium. Dilute *acids* also do not decompose it in the cold, but heating, ammonia is produced, and hydride of salicyl is set free. With an alcoholic ution of *sulphydric acid*, it yields hydride of sulphosalicyl:

$$\underset{\text{Hydrosalicyl-amide.}}{C^{21}H^{15}N^2O^3} + 3H^2S = \underset{\text{Hydride of sulpho-salicyl.}}{3C^7H^6OS} + 2NH^3.$$

Hydrosalicylamide forms several salts in which part of the hydrogen is replaced by allic radicles.

The *cupro-cuprammonic salt*, $C^{42}H^{30}Cu^2(N^2H^6Cu)''N^4O^6$, is obtained by mixing a very ute and slightly cooled alcoholic solution of hydrosalicylamide with ammoniacal tate of copper (acetate of cuprammonium). The liquid immediately acquires a fine erald-green colour, and gradually deposits brilliant laminæ of the same colour, the ution being at the same time decolorised. The crystals are insoluble in water and alcohol; they dissolve in cold dilute acids, but are reprecipitated on saturating the ution with an alkali. Strong mineral acids decompose them completely, liberating ride of salicyl. Dilute potash does not decompose them without the aid of heat, even then but slowly. They melt when heated, and yield by distillation an oil ch solidifies on cooling, in a crystalline mass having the odour of gum-benzoin.

Ferrico-ferricammonic salt, $C^{21}H^{15}fe^2(NH^3fe)N^2O^3$*.—To prepare this salt, an aqueous

* $fe = \frac{1}{2}$ Fe = 18½.

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h a quantity of tartaric acid sufficient to prevent
mmonia; a saturated alcoholic solution of hydro-
uantity of ammonia sufficient to enable it to be
of cold water without becoming turbid; and the
e immediately acquires a deep blood-red colour,
wish-red flocculent precipitate which gradually
This precipitate is partially soluble in alcohol.
ydrochloric acid, but the hot concentrated acid
ide of salicyl.
ar to exist. One of them is obtained by mixing
imes its volume of alcohol, heating the mixture,
ing an alcoholic solution of hydrosalicylamide
onia till the precipitate which forms at first no
is liquid on cooling deposits a yellow granular
salicylamide is obtained by mixing a solution of
, and adding in the cold a solution of acetate of
med, which become strongly electric by friction.

$^{21}H^{15}Br^3N^2O^3$ = $N^2(C^7\ddot{H}^5BrO)^3$. *Hydride of* ined by the action of ammonia on hydride of Its properties and reactions are precisely analo-
id. (Piria.)

$^{21}H^{15}Cl^3N^2O^3$ = $N^2(C^7\ddot{H}^5ClO)^3$. *Hydride of* a, Ann. Ch. Phys. [2] lxix. 309).—Produced by of chlorosalicyl (chlorosalicylous acid):

= $C^{21}H^{15}Cl^3N^2O^3$ + $3H^2O$.

ia gas over dry chlorosalicylous acid, the gas is s formed. To complete the reaction, it is neces-to time, pulverise it, and again submit it to the ien crystallised from absolute alcohol, or better

in small yellow scales, tasteless, nearly insoluble ier, especially with aid of heat. Absolute alcohol ot aqueous alcohol decomposes it, eliminating d or alkaline liquids.

variety of augite, occurring in amorphous masses Palagonia and Aci Castello in Sicily, associated and calcite. According to v. Waltershausen, it 9 CaO, 3·41 MgO, 2·51 Na^2O, 2·67 K^2O, 15·06 soluble matter. (*Rammelsberg's Mineralchemie,*

from Göpfersgrün, in which Klaproth found 59·5

mineral, translucent in thin folia, from Snarum n serpentine. Hardness = 2·0 (Hochstetter). erg). It dissolves easily and with effervescence ignition. Hermann examined a mineral (which al with this, from Scheschemskaja Gora in the te, together with chlorospinel, hydrargillite, and s to form six-sided prisms cleaving perfectly gravity = 2·04.
r. Chem. xxvii. 376).—*b*—*e*. by Rammelsberg ann (J. pr. Chem. xlvi. 237).

	c.	*d.*	*e.*	*f.*
·25	17·78	18·00	18·87	16·96
·27	38·18	37·30	37·04	37·08
·61	6·05	7·32	7·30	3·92
·59	37·99	37·38	37·38	42·04
·72	100·00	100·00	100·59	100·00

lyses, abstracting the carbonic acid, lead to the ^2O) or $(Al^2)^{vi}H^8O^{9}.5—6Mg''H^4O^2$.

TE. An altered form of asbestiform tremolite nd in Scotland.

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HYDROZINCITE. See ZINC-BLOOM.

HYDURILIC ACID. $C^8H^6N^4O^6$.—An acid belonging to the uric acid gr discovered by Schlieper (Ann. Ch. Pharm. cvi. 11), and further investigated Baeyer (*ibid.* cxxvii. 11). Schlieper, who assigned to it the formula $C^{12}H^9N^3$ once obtained it accidentally in treating uric acid with dilute nitric acid, and conc trating the mother-liquor remaining after the alloxan (i. 135) had crystallised c but he did not succeed in preparing it a second time. It was really produced by decomposition of dialuric acid, which is one of the products of the action of nitric a upon uric acid (ii. 965), and in Schlieper's experiment was decomposed by the hea the sand-bath in which the syrupy liquid had been allowed to remain.

Baeyer obtains hydurilic acid by heating dialuric acid with glycerin (which merely as a solvent) to about 160°, the dialuric acid then splitting up into hyduril of ammonium, formic acid, and carbonic anhydride:

$$\underset{\text{Dialuric acid.}}{5C^8H^6N^2O^4} = \underset{\text{Hydurilate of ammonium.}}{2C^8H^5(NH^4)N^4O^6} + CH^2O^2 + 3CO^2.$$

Preparation from Uric acid.—The uric acid is first converted into alloxan Schlieper's method of oxidation with hydrochloric acid and chlorate of potassi (i. 135); and the alloxan, after being dissolved in lukewarm water, filtered from the altered uric acid, and decolorised if necessary with pure animal charcoal, is conver into dialuric acid by reduction with stannous chloride. For this purpose, a quant of tin equal to the weight of uric acid employed, is dissolved in excess of str hydrochloric acid; the still hot liquid is added all at once to the alloxan solution; more hydrochloric acid is added till the volume of the liquid amounts to 4 litres fo pound of uric acid decomposed. The preceding proportions must be carefully observ for with a smaller proportion of tin, alloxantin is obtained instead of dialuric ac and unless a large excess of hydrochloric acid is used, dialurate of tin separates hard crusts, very difficult to decompose. On leaving the strongly acid solution stand for a day, dialuric acid crystallises out in yellowish stellate groups of short fo sided prisms, which must be quickly washed, and dried in a vacuum. The quan obtained amounts to about 50 per cent. of the uric acid employed.

To convert the dialuric acid into hydurilic acid, 9 pts. of the perfectly dry substa is mixed in a capacious flask with 5 pts. of concentrated glycerin (as it is obtained evaporation in a basin till its temperature rises to 160°), and heated in an oil-bath to 1 —150°. A brisk and regular evolution of carbonic anhydride then takes place, and soon as this ceases and the contents of the flask have become solid, the temperatur raised for a short time to 160°, and the glycerin, after cooling, is removed by washi A yellowish-white granular powder is then left, consisting of acid hydurilate ammonium (p. 221). The glycerin takes no part in the reaction, but acts merely a solvent.

To obtain the free acid, it is best to convert the acid ammonium-salt into a copper-s and decompose this salt with hydrochloric acid. The crude ammonium-salt is dissol in boiling water, ammonia is added in slight excess, and solution of cupric sulphat added to the filtrate. The liquid then assumes a dark-green colour, and, if hot, depo on cooling red warty crystals of neutral hydurilate of copper. This salt is then composed by hot hydrochloric acid, and the hydurilic acid which crystallises out washed with dilute hydrochloric acid and dried over the water-bath.

Properties.—Hydurilic acid prepared as above forms a bulky white powder havin yellowish tinge; by once re-crystallising it from water, it may be obtained quite p and colourless. It is very sparingly soluble in cold *water*, somewhat more in hot wa and crystallises therefrom on cooling in small four-sided prisms containing 4 at. wa $C^8H^6N^4O^6.4H^2O$. It is also but very slightly soluble in *alcohol*, which, however, d not precipitate it from the aqueous solution.—*Sulphuric acid* dissolves it without composition, and on adding water, part of the hydurilic acid separates out again. *hydrochloric acid* it is even less soluble than in water, and is gradually precipita by it from the aqueous solution. From a hot concentrated solution in hydrochl acid, or from an ammoniacal solution decomposed by hydrochloric acid, it separ as a crystalline powder consisting of rhombic tablets containing 2 at. water of cr tallisation: $C^8H^6N^4O^6.2H^2O$. The water, amounting to 6·86 per cent. (2 at. = 6 is given off at 140°.

Hydurilic acid bears a tolerably high temperature without decomposition; it li wise offers considerable resistance to the action of *alkalis*, being attacked but slo and without blackening, by melting potash, with formation of oxalic acid. It is attacked by reducing agents; but *oxidising agents*, such as *chlorine*, *bromine*, *nitric a oxide of silver*, *peroxide of lead*, and *sesquichloride of iron*, attack it very quic yielding various products. When heated with *ferric chloride*, it yields oxy

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durilic acid, an acid not yet examined, but characterised by the blood-red colour which it produces with ferric salts. With a mixture of *hydrochloric acid and chlorate of potassium*, hydurilic acid yields dichloro-hydurilic acid, $C^8H^4Cl^2N^4O^6$.—Fuming *nitric acid* converts it into alloxan without any other product; but with nitric acid of ordinary strength, it yields alloxan together with violuric acid, violantin and dilituric acid (ii. 965). If the action be carried on to the end, with aid of heat, the only product is dilituric acid*; but if it be interrupted at an earlier stage, a mixture is obtained, varying in composition according to the duration of the action:

$$\underset{\text{Hydurilic acid.}}{C^8H^6N^4O^6} + NHO^3 = \underset{\text{Violuric acid.}}{C^4H^3N^3O^4} + \underset{\text{Alloxan.}}{C^4H^3N^2O^4} + H^2O;$$

$$\underset{\text{Hydurilic acid.}}{C^8H^6N^4O^6} + 2NHO^3 = \underset{\text{Dilituric acid.}}{C^4H^3N^3O^5} + \underset{\text{Alloxan.}}{C^4H^3N^2O^4} + NHO^2 + H^2O.$$

Dilituric acid may indeed be regarded as a product of the oxidation of violuric acid, $C^4H^3N^3O^5 = C^4H^3N^3O^4 + O$; and violantin, $C^8H^6N^6O^8$, is a compound of the two. With *nitrous acid*, the same products are obtained. With nitrite of potassium and excess of nitrous acid, the products are violurate of potassium and alloxan:

$$\underset{\text{Hydurilic acid.}}{C^8H^6N^4O^6} + NKO^2 + 2NHO^2 = \underset{\text{Violurate of potassium.}}{C^4H^2KN^3O^4} + \underset{\text{Alloxan.}}{C^4H^3N^2O^4} + 2H^2O + 2NO$$

Hydurilic acid is most distinctly characterised by the splendid dark-green colour which the acid and its salts produce in a solution of *ferric chloride*. The colour is destroyed by strong acids and alkalis, also by heat, the hydurilic acid then decomposing and the colour changing to red. Characteristic also are the chalk-white precipitates produced on adding hydrochloric acid to the alkaline solution, and the reactions with hydrochloric acid and chlorate of potassium and with nitric acid, just mentioned.

Hydurilates. Hydurilic acid is dibasic, yielding both acid and neutral salts. It dissolves easily in ammonia, potash, and soda, forming moderately soluble salts; the other hydurilates are sparingly soluble or insoluble. These salts cannot, however, in general be obtained by double decomposition, since the acid has a great tendency to form double salts; they must therefore be prepared with the free acid. The acid decomposes most metallic chlorides, forming acid salts; also acetates, with formation of neutral salts, excepting in the case of the ammonium- and potassium-salts.

Hydurilates of Ammonium.—The *acid salt*, $C^8H^5(NH^4)N^4O^6$, obtained by heating dialuric acid in glycerin (p. 220), is nearly pure, having only a faint yellowish colour. It is moderately soluble in boiling water, and separates, on cooling, in crusts and granules. By solution in hot dilute ammonia, and precipitation with acetic acid, it is obtained quite pure, in small octahedral crystals, which, however, soon lose their form. Strong acids remove only part of the ammonia. The crystals are anhydrous.

The *neutral-salt*, $C^8H^4(NH^4)^2O^6$, is obtained by mixing the acid salt with ammonia, and separates from a hot saturated solution by rapid cooling in needles containing 2 at. water; it is also obtained in the same form by precipitation with sulphide of ammonium, in which it is insoluble. The solution when left to stand, or slowly evaporated, deposits large shining monoclinic prisms, with dihedral summits, containing 4 at. water, and efflorescing, with loss of water and ammonia, when exposed to the air. (For Rammelsberg's determination of the form of these crystals, see Ann. Ch. Pharm. cxxvii. 19.) The salt is moderately soluble in water, very easily in ammonia, and is completely precipitated therefrom by alcohol in amorphous flocks or in needles.

Hydurilate of Barium (neutral), $C^8H^4Ba''N^4O^6.2H^2O$, is obtained as an amorphous precipitate, which soon becomes crystalline, on adding a hot solution of hydurilic acid to acetate of barium.

Hydurilates of Calcium.—The *acid salt*, $C^{16}H^{10}Ca''N^8O^{12}.16H^2O$, separates, on adding hydurilic acid to a solution of chloride of calcium, in small shining prisms, insoluble in water. The *neutral salt*, $C^8H^4Ca''N^4O^6.6H^2O$, is obtained by decomposing acetate of calcium with hydurilic acid, as an amorphous precipitate, which becomes crystalline on standing. It gives off 2 at. water at 130°.

Hydurilates of Copper.—The *acid salt*, $C^{16}H^{10}Cu''N^8O^{12}.16H^2O$, is obtained by adding cupric acetate to excess of hydurilic acid, or by mixing the acid with cupric sulphate. From concentrated solutions it separates in green needles; from more dilute solutions, in thin prisms of a shining yellow colour. It is decomposed by excess of

* Schlieper's "nitro-hydurilic acid," obtained by the action of hot nitric acid on hydurilic acid, was most probably dilituric acid containing potash, derived from the impure hydurilic acid used. (Baeyer, Ann. Ch. Pharm cxxvii. 211.)

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strong acids. When heated, it gives off the whole of its water, and is converted a red powder of the anhydrous salt, which is also precipitated immediately from solutions.

The *neutral salt*, $C^8H^4Cu''N^4O^6.8H^2O$, is obtained by adding hydurilic acid to ex of cupric acetate, or by mixing the neutral ammonium- or sodium-salt with cu sulphate. Cold dilute solutions yield a red precipitate of the hydrated salt, consis of short needles; warm concentrated solutions, a dark brown-red precipitate of anhydrous salt. The red salt is converted by heat into the brown salt, giving off water, but recovers it in contact in water. The salt is decomposed by excess of hy chloric acid, yielding hydurilic acid and chloride of copper.

Hydurilates of Iron.—The ferric salt is a dark green, easily decomposible cipitate; the *ferrous salt* is a white precipitate which soon turns green.

Hydurilate of Lead is a white precipitate, insoluble in acetic acid, insolubl water, soluble in nitric acid; obtained by adding hydurilic acid to neutral ace of lead.

Hydurilate of Potassium has not been obtained in definite form. A solutio hydurilic acid in potash mixed with acetic acid, yields hydurilic acid contain variable quantities of potash; alcohol also throws down from the same solutio substance containing more potash than the neutral salt would contain.

Hydurilate of Silver.—Acetate of silver forms with hydurilic acid small shin prisms, which soon turn grey: with a cold solution of hydurilate of ammonium forms a white precipitate; with a warm solution, crystals which soon turn black. boiling the silver-salt with water, silver is reduced, and the hydurilic acid is oxidi forming oxyhydurilic acid (p. 221).

Hydurilate of Sodium, $C^8H^4Na^2N^4O^6.H^2O$, is obtained by acidulating a solut of hydurilic acid in strong soda-ley with acetic acid, and adding alcohol. The neu salt then separates in small, colourless, shining prisms, which are moderately solu in cold, easily in hot water. The acid-salt does not appear to exist.

Hydurilates of Zinc.—The *acid salt*, $C^{16}H^{10}Zn''N^8O^{12}$, crystallises from a solut of zinc-chloride mixed with hydurilic acid, in beautiful feathery groups of need having a strong lustre. The *neutral salt*, $C^8H^4Zn''N^4O^6.4H^2O$, separates on mix hydurilic acid with excess of zinc-solution, as a white amorphous precipitate, wh soon becomes crystalline.

Dichlorohydurilic acid. $C^8H^4Cl^2N^4O^6$.—This compound is prepared on add chlorate of potassium by small portions, and with constant stirring, to a pasty mixture hydurilic and strong hydrochloric acid. A snow-white powder is thus obtained, which very slightly soluble in water, either hot or cold, and is most easily purified by dissolv it in strong sulphuric acid, which exerts but little action on it, but thickens when hea with it over the water-bath, and, on gradual addition of water, deposits the chlorina acid in small rhombic crystals, containing $C^8H^4Cl^2N^4O^6.4H^2O$. It is especially p manent in acid liquids, is not attacked by chlorine, and but slowly by warm ni acid, with formation of dilituric acid, but is easily decomposed by alkalis.

Dichlorohydurilic acid is a strong dibasic acid, which dissolves in alkalis, especia with aid of heat, and is reprecipitated by hydrochloric acid. The solutions turn on boiling, yielding a metallic chloride, and an acid not yet examined.

The *neutral potassium-salt*, $C^8H^2K^2Cl^2N^4O^6.4H^2O$, crystallises from a warm solut of potash saturated with the acid in small, beautiful six-sided tables. It dissol sparingly in cold, more readily in hot water. It retains its water of crystallisation 120°; at a stronger heat it turns red and decomposes.

HYGRINE. (Wöhler and Lossen, Ann. Ch. Pharm. cxxi. 374.—Loss *Dissertation.*)—An organic base occurring, together with cocaïne, in coca-lea (i. 1059). To extract the two bases, the leaves are exhausted with rain-water a temperature of 60° to 80°; the united extracts are precipitated with neutral acetate lead and filtered; the filtrate is precipitated with a saturated aqueous solution sulphate of sodium, again filtered and concentrated; and the concentrated liquid, af being rendered slightly alkaline by carbonate of sodium, is agitated four or six tir with ether to extract the cocaïne. The remaining liquid mixed with an additio quantity of carbonate of sodium, and again shaken with ether, yields hygrine an neutral oil having the odour of tobacco. These substances remain when the ether distilled off; and on further heating the residue, till it boils, the temperature quic rises to above 280°, and a brown alkaline oil distils over, while a black resin is behind. When the distillate is maintained at 140°, for some hours, in a stream hydrogen, the greater part passes over of a yellow colour (*a*), while the remain volatilises only at 140° to 230°, and condenses to a thick brown oil (*b*). Hygrine contained in both portions; that in *b*, however, is contaminated with a neutral

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that in *a* with an easily volatilised substance. To remove a little ammonia present, *a* is converted into oxalate, the salt is dissolved in absolute alcohol, the solution evaporated, and the residue mixed with caustic potash, which separates the hygrine in the form of oil. The alkaline solution is heated to boiling in a stream of hydrogen, when the hygrine, dissolved in the water, passes over (by adding water to the residue and again distilling to dryness, a further quantity may be obtained), and is extracted from the distillate by ether; on again distilling the ethereal solution, the hygrine remains behind. The neutral oil in *b* is removed by dissolving *b* in water containing hydrochloric acid, shaking the solution with ether, and separating the ethereal layer; after which, the acid solution is supersaturated with caustic soda, and the hygrine taken up by ether, as in the treatment of *a*. (Lossen.)

Hygrine is a thick, pale-yellow oil, having a strong alkaline reaction, a burning taste, and an odour of trimethylamine. It produces white clouds with the volatile acids; distils very slowly with vapour of water. It does not appear to be poisonous.

Hygrine does not dissolve in *water* in all proportions. The aqueous solution forms a white precipitate with *dichloride of tin*, yellowish with *sulphate of iron*, light blue with *sulphate of copper;* on boiling the solution, the copper precipitate becomes granular, but not brown. Hygrine forms white precipitates with *chloride of mercury* and *nitrate of silver;* the silver precipitate quickly turns brown.

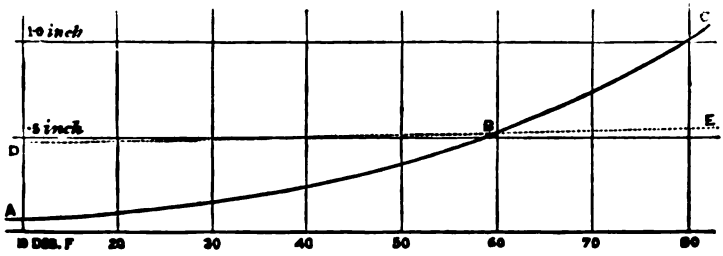
Hygrine combines with *hydrochloric acid*, forming deliquescent crystals. The aqueous hydrochlorate forms a brown flocculent precipitate with *di-iodide of potassium*, red-white with *dichloride of tin*, white with *corrosive sublimate*, partly flocculent and partly in oily drops. With *tetrachloride of platinum* it forms dirty white-yellow (or red) flakes, which are decomposed by heating the liquid, and do not appear in very dilute solutions. *Picric acid* throws down from hydrochlorate of hygrine a yellow powder; *gallotannic acid*, a white precipitate.

Hygrine dissolves in *alcohol* and in *ether*.

HYGROMETER. HYGROMETRY. A Hygrometer (*hygrós*, moist; *métron*, measure) is any instrument which measures the amount or degree of moisture in the atmosphere. There are, however, several kinds of hygrometers which measure, or are said to measure moisture, by entirely different modes, and the problem itself—to estimate the degree of moistness of the air—is found on examination to be quite ambiguous. It is therefore necessary to attend to the principles of the subject.

Principles of Hygrometry.—Water, both liquid and solid, always tends to assume the gaseous form, and in so doing exerts an elastic force increasing as the temperature rises. In *fig.* 565 the curve ABC is drawn so as to represent the law of the elastic force of aqueous vapour: if the divisions along the horizontal axis represent the tem-

Fig. 565.



perature of the water in degrees Fahr., the perpendicular lines drawn from them to the curve, being measured, will give the corresponding force of its vapour estimated in the height of the column of mercury which it would be able to sustain.

The elastic force obviously increases in a higher ratio than the temperature, and, in order that such increasing force may be exerted when water is confined in a given space, it is necessary that a larger and larger quantity of water should become vapour. It is true that if the weight of vapour be not increased, its elastic force will rise with its temperature, but in a much less ratio. For aqueous vapour, like any other gas, tends to expand by $\frac{1}{491}$th part of its volume at 32° F. for every degree of increased temperature. Thus, if the vapour which rises from water at the temperature of 60° F. and has the elastic force of ·518 inch be confined in the same space, but apart from water, and heated, its elastic force will rise in a manner represented by the straight line BE (*fig.* 565); but if more water be present to supply additional vapour, the elastic force of the whole vapour would rise, as shown by the curve BC.

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On the other hand, if the vapour at 60° F. be cooled, it will, as a gas, tend to exert an elastic force falling as the straight line BD. But the elastic force which liquid water exerts falls more rapidly, as shown by the curve BA; hence part of the vapour must be condensed to the liquid condition until the elastic force of the remainder is not greater than that which rises from water at that temperature. The following definitions will now be understood. Aqueous vapour is said to be *saturated*, and of *maximum elastic force*, when any reduction of temperature, or any increase of pressure, would cause some of the vapour to be condensed. The temperature of saturated vapour is said to be at the dew-point. Thus aqueous vapour of 60° F. and of an elastic force of ·518 inch is saturated, and 60° is its dew-point. Any portion of aqueous vapour has a dew-point; for the temperature may always be reduced so low that a portion will be condensed by any further reduction.

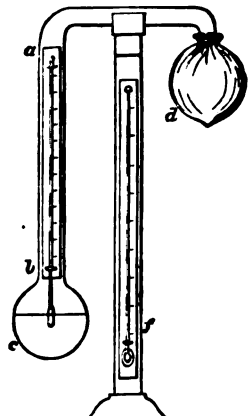
What is true of aqueous vapour alone is also true of aqueous vapour mixed with air: for it is a law that mixed gases do not exert their pressure upon each other. The only difference is, that vapour does not spread so rapidly into a space occupied by air as it does into a vacuous space. In an *indefinitely small space*, then, the vapour and air may be considered perfectly independent of each other. The larger the volume, the longer do we need to wait until diffusion has produced perfect mixture.* Air is said to be saturated with moisture when the aqueous vapour it contains is of maximum elastic force. The temperature of the air is then called its dew-point—for any reduction of temperature would cause the condensation of some vapour in the form of *dew* particles.

The *degree of humidity*, or *of saturation*, is the ratio which the vapour in the air bears to what it might contain. (See HEAT, pp. 81, 83.)

Condensing Hygrometers are those which, by cooling the air until the contained vapour begins to be condensed, indicate the dew-point, and thus enable us to learn the elastic force of the vapour. Dalton first proposed this method of Hygrometry, using a cup of cold water. Le Roi proposed the use of ice for this purpose; and in the absence of any hygrometer, the dew-point may be ascertained very accurately, by exposing to the air a small bright metal cup, for instance a platinum crucible, containing water cooled by ice or by some salt, such as sal-ammoniac or nitrate of ammonium, dissolved in it. The water is to be stirred with the bulb of a small thermometer, and the degree noted at which dew begins to form or to evaporate on the bright metallic surface.

Daniell's *Hygrometer* was the first accurate instrument invented, and may still be used to determine the dew-point with considerable ease and exactness (*Daniell's Meteorological Essays*, p. 127). It consists (*fig.* 566) of a small glass siphon, at each end of which is a thin glass bulb about 1¼ inch in diameter. The longer leg *ab* is about 4 inches long and contains a small but very delicate thermometer, the bulb of which is within the terminal glass ball. The siphon contains so much common ether as when poured into the lower bulb *c* will rather more than half cover the enclosed thermometer-bulb. Before the tube is sealed up, the ether is boiled, so as to drive out the whole of the air. The essential part of the instrument is completed by covering the upper bulb *d* with muslin and gilding a part of the lower bulb. It is now usual, however, to make this lower bulb of black glass. The siphon-tube is placed for use upon the little stand which contains the second thermometer *f*, in order that the temperature of the air may be observed at the same time as its dew-point.

Fig. 566.



To make an observation, all the ether within the instrument is first poured into the lower bulb. Then taking a bottle of common ether, a few drops are poured upon the muslin of the upper bulb. Its evaporation cools the bulb and condenses the ether vapour within. Fresh vapour flows along the bent tube from the lower bulb, and, in the manner of Wollaston's *cryophorus*, the temperature of this lower bulb is gradually reduced, until the dew-point of the surrounding air is reached, and dew may be observed forming upon the gilded or blackened surface of the bulb. The dew-point, as shown by the included thermometer, is then to be read, but accuracy is only to be attained by observing several successive depositions

* A neglect of this fact has led many eminent meteorologists to consider the atmosphere as composed of two independent atmospheres, namely of aqueous vapour and of the other gases. Nothing can be more erroneous.

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and evaporations of dew in a manner fully described under the head of Regnault's Hygrometer.

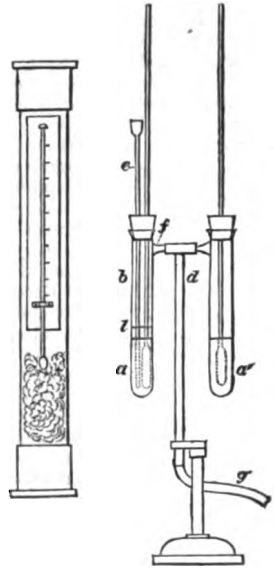
The hygrometer of Daniell, however elegant and pleasing in theory, has many sources of inconvenience and inaccuracy. The expenditure of ether is considerable and costly, and in a hot and dry climate it is very difficult to obtain any deposition of dew, during the long-continued manipulation and close observation of the instrument which is always necessary. The warmth and moisture of the hand and body are sure to affect the indications of both thermometers. The cold ether vapour flowing from the upper bulb may also cause inaccuracy. The last and most important objection is that cold is produced only at the surface of the ether in the lower bulb, and there is no agitation of the liquid to ensure uniformity of temperature. Hence the internal thermometer may often indicate a temperature some degrees different from that at which dew is being deposited. This objection is partially remedied by making the lower bulb oblique, so that one part of it shall be nearly in contact with the thermometer-bulb within. Daniell, well aware of this objection, remarks that dew will first be deposited in a circle round the bulb near to the surface of the ether, and directs that the thermometer-bulb shall be placed so as to be cut by the surface of the ether.

Subsequent to Daniell's invention, several dew-point instruments were devised, in which the evaporation of ether was made to cool the bulb of a thermometer and cause a deposit of dew, either upon the bulb or a metallic capsule in a more simple manner. Such is that of Jones (Phil. Trans. [1826] cxvi. pt. ii. 53). Of a similar nature are the *hygromètre à capsule* and the *hygromètre à virole d'or* of Pouillet (Élém. de. Phys. [7th ed. 1856] ii. 739). That of M. Belli (Ann. Ch. Phys. [3] xv. 506) is different and very ingenious, giving a continual indication of the dew-point.

Connell's *Hygrometer*, very lately proposed, and to some extent, we believe, brought into use, consists of a thermometer with its bulb immersed in ether, contained within a small metal globe. A common exhausting syringe is used to cause the evaporation of the ether, and the dew-point is then ascertained, exactly as in Daniell's or Regnault's hygrometer. This method presents some slight advantages over Daniell's, but retains all its worst causes of error and inconvenience. It is also an expensive instrument, and cannot compare with Regnault's Condenser Hygrometer either in theory or in practice. It is described in the Transactions of the Royal Society of Edinburgh xxi., and Phil. Mag. [4] viii. 81.

Dr. George Cumming's *Hygrometer* (Quar. Jour. of Sci. &c. 1828, Jan. to June, p. 403) seems first to have introduced a method now finally adopted as the best. It consisted (*fig.* 567) of a thin glass or metallic tube containing a delicate thermometer enveloped in sponge or other porous substance, upon which a little ether was to be poured. Almost any degree of artificial cold could then be produced by a stream of air from a pair of bellows, or other pneumatic contrivance. The only important objection to this instrument is the presence of a spongy or porous substance, which would prevent perfect uniformity of temperature within the tube.

Fig. 567. *Fig.* 568.



Döbereiner further proposed a hygrometer in which a current of air from a forcing pump is made to traverse the ether, disposed as in Daniell's instrument, and thus produce cold by evaporation. (Pogg. Ann. lxv. 339.)

Regnault's *Condenser Hygrometer* (Ann. Ch. Phys. [3] xv. 129) may be described as a perfect instrument of its kind. In its complete form (*fig.* 568) it consists of a very thin and brightly polished silver thimble *a*, 45 mm. high and 20 mm. in diameter, fitted to the glass tube *b*, which again is fixed by the small lateral tube *t*, and the metallic tube *d*, to the stand. The upper end of the glass tube *b* is closed by a cork, bearing a thin glass tube *e*, descending nearly to the bottom of the silver thimble, and a very delicate and accurate thermometer, the pear-shaped bulb of which is in the centre of the thimble. A second exactly similar thermometer, similarly placed within a glass tube and silver thimble, is mounted on the other side of the stand, but the cork is not penetrated by any glass tube.

To make an observation, so much good ether is poured into the tube *b* as will rather

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more than fill the thimble to the level *l*, and the cork being fitted in air tight, the instrument is put in connection, by means of the caoutchouc tube *g*, with a common aspirator, by which an exactly regulated flow of air through the instrument may be obtained. The aspirator, which may have a capacity of 3 or 4 litres (3 or 4 quarts) is placed close to the observer, and the hygrometer may be at some distance, for instance outside a window, being observed, if necessary, with a telescope.

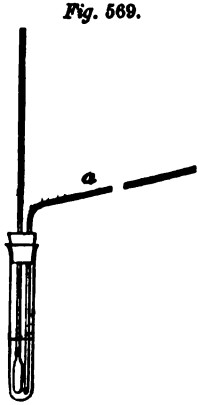
Now when water is allowed to flow from the aspirator, air is drawn through the tube, and bubbling up through the ether, causes a more or less rapid evaporation. The temperature of the ether is thus slowly reduced, and from its constant agitation by the stream of air, the silver thimble and the thermometer-bulb are maintained at an exactly similar temperature. After a minute or two at the most, dew will begin to form on the thimble and will be very visible on its brightly polished surface. The thermometer is instantly to be read, and the stream from the aspirator to be stopped. Suppose that the reading observed is 48·1° F., the deposit of dew may increase for a few moments, but will soon begin to evaporate again, the thermometer rising. At the moment that the dew entirely disappears, read the thermometer again; let it be 49·3. Considering that dew requires a short time to form or evaporate in a visible degree, it is obvious that the dew-point lies between 48·1 and 49·3. Let an exceedingly slow current of air be now drawn through the ether, so that the thermometer is very gradually reduced to 49·2, 49·1, 49·0, and so on. The point at which dew first appears may now be observed with much greater accuracy; let it be 48·8. Still it is probable that 48·8 is somewhat below the exact dew-point. If, when the current is stopped, the small deposit of dew vanishes at 49·0, we may consider the mean, or 48·9, to be the true dew-point; but if necessary we may, by still slower procedure, approximate even more closely. "All these operations," observes M. Regnault, "take more time to describe than to execute; with a little practice, three or four minutes are sufficient for determining the dew-point almost within $\frac{1}{10}$ of a degree Centigrade."

At the same time, the second thermometer is to be read, to give the common temperature of the air. From its parallel circumstances and position, its indications would be exactly similar to those of the other; hence the difference of the two gives the depression of the dew-point free from almost all kinds of error. It is obvious that all the objectionable points in Daniell's hygrometer are avoided in this admirable instrument. The only remaining objection is the inconvenience of keeping or carrying about a large aspirator, and frequently filling it with water. In the Kew Observatory, the aspirator is in the form of a circular bellows, to the lower movable board of which a weight is attached. Mr. Welsh also proposed to expand the upper end of the tube *e* into a small funnel by which fresh ether may readily be introduced.

Lieut. Noble has obtained dew with this hygrometer, at all temperatures down to −35°, the limit of graduation of his thermometer, the only requisites when the dew-point is very low being patience and pure ether. (Phil. Mag. [4] xi. 305.)

Several London instrument-makers have rendered this instrument less expensive by omitting the second thermometer and its appendages. They have likewise substituted a closed tube of black glass for the polished silver thimble. This is, on the whole, an improvement, for the dew is even more visible on the black surface, and the difficulty of maintaining the silver bright is avoided; but on the other hand the uniformity of temperature is not so rigorously ensured. As regards the temperature of the air, we think it is best learnt by an ordinary thermometer freely exposed, and that Regnault's parallel arrangement of the second thermometer, although beautiful in theory, is actually erroneous and undesirable in the ordinary use of the instrument.

Fig. 569.



Except, however, for refined researches or long continued series of observation, a much simpler apparatus will serve. The practical chemist has only to take a common test-tube, containing about 1½ inch depth of ether, insert somewhat loosely a delicate tube-thermometer and glass tube, as shown in *fig.* 569, and gently blow with the mouth through the bent tube *a*, and the whole process of observation can be conducted almost as well as in Regnault's complete instrument. It is necessary to have the tube *a* of considerable length, that the moistness and warmth of the body and the breath may not affect the air surrounding the tube. The writer had used such an apparatus daily for many months before noticing that Regnault mentions its successful use.

Hygrometry by Evaporation.—Dr. Hutton of Edinburgh first suggested that the degree of cold produced by the evaporation of water in the air, would depend upon and therefore indicate the moistness of the air. Leslie again

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slie, *On the Relations of Air to Heat and* practice by covering one of the bulbs of his uslin. The motion of the column of water the depression of the temperature of evapo- ink, be often used in certain researches, and lass.

ed on the Continent the *Psychrometer* (ψυχρός, similar delicate thermometers placed in a nometer being covered with muslin and kept mall reservoir of rain or distilled water. The temperature of the air; the other will be re said to be that of evaporation, which is air. In saturated or moist air, the thermo- s in some proportion to the *dryness* of the air, of the dryness in many practical matters, halls, plant-houses and so on.

bulb thermometers, it is further possible, by experiment, or by calculation from *à priori* on of aqueous vapour, and other hygrometric n reductions is the following, which has been bination of all the simultaneous observations th Daniell's hygrometer, taken at the Royal 41 to 1854, with some observations taken at Toronto.

ply the difference of reading of the thermo- b reading, and subtract the product from the

Dry-bulb thermo-meter F.	Factor.	Dry-bulb thermo-meter F.	Factor.
56°	1·94	78°	1·69
57	1·92	79	1·69
58	1·90	80	1·68
59	1·89	81	1·68
60	1·88	82	1·67
61	1·87	83	1·67
62	1·86	84	1·66
63	1·85	85	1·65
64	1·83	86	1·65
65	1·82	87	1·64
66	1·81	88	1·64
67	1·80	89	1·63
68	1·79	90	1·63
69	1·78	91	1·62
70	1·77	92	1·62
71	1·76	93	1·61
72	1·75	94	1·60
73	1·74	95	1·60
74	1·73	96	1·59
75	1·72	97	1·59
76	1·71	98	1·58
77	1·70	99	1·58

meter stand at 64·3° F., and the wet-bulb at

= difference of readings.

4°, the nearest degree to 64·3:

= 57·9° = dew-point.

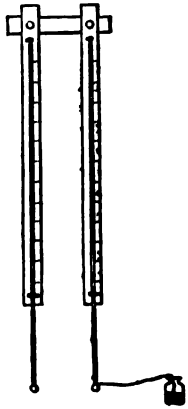
for reduction of dry and wet-bulb readings he probable error and measure of precision of from observations at Toronto.

having long become the ordinary working

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hygrometer of the meteorological observer, Mr. Glaisher has paid much attention to the perfecting of the instrument in every detail. He has finally adopted a pair of very delicate thermometers (see *fig.* 570) about one foot long, and with small spherical bulbs of thin glass of about ¼ inch diameter. They are mounted upon metal scales graduated from about −10° to +130° F. and fixed parallel to each other from 2 to 4 inches apart upon a metal cross piece. Care is taken that each pair of thermometers is as exactly similar as possible. The bulb of the wet thermometer is covered with thin muslin, round the neck of which is twisted a conducting thread of lamp-wick, common darning cotton, or floss silk; this passes into an adjacent vessel of water placed about three inches distant from the wet bulb, a little beneath it, and on the opposite side to the dry-bulb thermometer. It is a very objectionable practice to place a long glass cistern between the two thermometers; for the water will seldom be of exactly the same temperature as the surrounding air, and will tend slightly to vitiate the readings of both thermometers. The writer prefers for a cistern a short narrow-necked glass bottle, from which but little evaporation will take place. The water must be either rain or distilled water. Care must be taken never to record any readings when the bulb is not thoroughly moist all over. As dust and saline particles gradually settle on the wet muslin, it is well to re-cover the bulb and supply a fresh wick about every month. Before use, too, each wick should be washed in a solution of carbonate of soda, and pressed whilst under water throughout its length. The supply of water to the bulb can be easily regulated by raising or lowering the cistern.

Fig. 570.



In taking an observation, the dry-bulb thermometer is first to be read, because it is most liable to change; the wet-bulb is then to be read, the two readings to be recorded, and a comparison with the thermometers made, to secure the correct number of whole degrees. The observer must follow the directions under the article THERMOMETER, as regards placing the instrument, correcting the thermometer-readings, &c.

The dry- and wet-bulb hygrometer continues to act even when the water is frozen, since evaporation still takes place; but especial care must be taken that the bulb really is covered with ice, and if not, water must be poured upon it, and the observation delayed till the water be frozen, and the thermometer sink to a constant reading. In frosty weather it is best to wet the bulb after every periodic observation, or at least ten minutes before the next.

Theory of the Psychrometer.—Although we may ascertain the dew-point from readings of the dry- and wet-bulb thermometers on purely experimental grounds, as in using Glaisher's factors, the subject also admits of mathematical investigation. Mr. Ivory first solved the problem (Phil. Mag. [3] lx. 80) with substantial correctness. August of Berlin, and Bohnenberger, showed the coincidence of the theory with experiment, and determined the constants with accuracy (August, *Ueber die Fortschritte der Hygrometrie in der Neuesten Zeit, Berlin*, 1830.—Bohnenberger, *Tubingen Nat. Hist. Soc. Memoirs*, vol. ii.). But the subject is best known in England from Dr. Apjohn's excellent results (Phil. Mag. [3] vi. 182; vii. 266, 470; xiii. 261).

We now give the investigation as it is stated by Regnault after the method of M. August.

The evaporation of a liquid involves the conversion of sensible into latent heat, and the supply of heat must be drawn from the liquid evaporated, from the remaining liquid, or from surrounding objects. When air is in contact with the moistened bulb of a thermometer, the evaporation of the water will reduce the temperature of the bulb, but the fall of temperature will be checked by heat communicated from the remainder of the air. At some point, the amounts of heat subtracted and communicated will be equal, and an invariable temperature of evaporation will be the result.

Let us suppose, with M. August, that the portions of air successively in contact with the moist thermometer-bulb become thereby perfectly saturated with moisture, and are reduced to the temperature of the bulb.

Let w = weight of stratum of dry air surrounding the bulb at 0° C., and under the pressure of 0·760.

h = height of barometer.

t = temperature of surrounding air given by the dry-bulb thermometer.

t' = temperature of evaporation, or the reading of the wet-bulb thermometer.

f and f' = the elastic forces of saturated aqueous vapour for the temperatures t and t'.

x = the actual elastic force of vapour in the air at the time.

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In the stratum of air surrounding the bulb, the aqueous vapour exerts the elastic force f', and the air consequently exerts the elastic force $h-f'$. The weight of dry air is then

$$w \cdot \frac{1}{1+\alpha t'} \cdot \frac{h-f'}{30},$$

α being the coefficient of expansion of a gas for every degree of temperature. The weight of vapour already in this air is

$$w\delta \cdot \frac{1}{1+\alpha t'} \cdot \frac{x}{30};$$

in which δ represents the specific gravity of aqueous vapour in relation to air. The weight of vapour added by contact with wet bulb similarly is

$$w\delta \cdot \frac{1}{1+\alpha t'} \cdot \frac{f'-x}{30}.$$

Now, if γ be the specific heat of air, the quantity of heat disengaged by the dry air in cooling from t to t' is

$$w \frac{1}{1+\alpha t'} \cdot \frac{h-f'}{30} \cdot (t-t') \cdot \gamma.$$

Similarly k being the specific heat of aqueous vapour, the quantity of heat disengaged by the vapour previously in the air is

$$w\delta \frac{1}{1+\alpha t'} \cdot \frac{x}{30} (t-t') \cdot k.$$

Lastly, let λ be the latent heat absorbed by water, when becoming gaseous between the temperatures t and t'.

The quantity of heat absorbed will be

$$w\delta \frac{1}{1+\alpha t'} \cdot \frac{f'-x}{30} \cdot \lambda.$$

Now when the temperature of evaporation is constant, this heat absorbed in evaporation must be equal to that given out by the air and the other portion of vapour; or we have, by equating them and striking out the factor $w \cdot \frac{1}{1+\alpha t'} \cdot \frac{1}{30}$,

$$\gamma(h-f')(t-t') + \delta k x (t-t') = \delta\lambda(f'-x);$$

whence

$$x = \frac{1 + \frac{\gamma}{\delta\lambda}(t-t')}{1 + \frac{k}{\lambda}(t-t')} f' - \frac{\frac{\gamma}{\delta\lambda}(t-t')}{1+\frac{k}{\lambda}(t-t')} \cdot h.$$

Inserting values of the known quantities, namely, for γ, 0·2669, for k, 0·2669 (the specific heat of aqueous vapour being assumed equal to that of air), for δ, the specific gravity of aqueous vapour, 0·6235, and for λ, the latent heat of aqueous vapour, $640 - t'$, according to the law of Watt, and neglecting some of the smaller terms, August obtains the formula $x = f' - \frac{0{\cdot}568\,(t-t')}{640-t'} \cdot h$, the temperatures being expressed in centigrade degrees.

Regnault, using more accurate data, namely, for δ, 0·622, and for λ, $610 - t'$ ($\gamma = k = 0{\cdot}2669$ as before), modifies this to

$$x = f' - \frac{0{\cdot}429\,(t-t')}{610-t'} \cdot h.$$

Experimentally, Regnault has found that the formula $x = f' - \frac{0{\cdot}480\,(t-t')}{610-t'} \cdot h$ gives an almost perfect coincidence between the calculated and true results, when the air is not more than $\frac{1}{10}$ saturated. Otherwise the first coefficient 0·429 is to be preferred.

The formula which has been most used in the reduction of dry- and wet-bulb observations is that obtained by Dr. Apjohn. In the Greenwich observations it is given as follows:

$$F = f - \frac{d}{88} \cdot \frac{h}{30} \qquad F = f - \frac{d}{96} \cdot \frac{h}{30}$$

The first formula is to be used when the reading of the wet-bulb is above 32° F., and the second when below. In the above, d is the difference of the dry- and wet-bulb readings, h the height of the barometer, f the elastic force of vapour for the temperature of the *wet-bulb*, to be taken from Table II., and F the elastic force of vapour at the dew-point, from which the dew-point may be found, if necessary, by the table.

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From a statement in *Daniell's Meteorology* [Essays, 1856] ii. 100, it would seem the errors of results obtained by Apjohn's formula, lie within closer limits than obtained by Glaisher's factors.

Taking the expression in the form

$$F = f - m.d.\frac{h-f}{30},$$

the term with $\frac{f}{30}$ being inconsiderable except at great heights, the following of the coefficient m have been given (for degrees Fahr.):

Ivory		·0139
Apjohn—*à priori* calculation		·01149
„ experiments on dew-point		·01151
„ „ refrigeration		·0115
„ other experiments		·0114
Bohnenberger—first 56 observations		·0114
„ second 45 „		·011398
Kaemtz	above 32° F.	·0118
„	below 32 F.	·0112
Kupffer	above 32 F.	·01135

The supposed great accuracy of many of these determinations has been some shaken by the later experiments of Regnault (Ann. Ch. Phys. [3] xv.), f finds that the temperature of evaporation is not invariable, but sinks lower, the gr the rapidity with which the air surrounding the wet bulb is moving. He is thu to doubt the soundness of August's assumption, that the stratum of air surroundin wet bulb is always saturated and of the same temperature as the bulb, and he cons that the radiant heat falling on the bulb is an element not to be neglected. ordinary formulæ, however, may be considered sufficiently accurate as long a velocity of the air does not exceed 5 or 6 metres (16 to 20 feet) per second.

We quite agree, however, with Dr. Drew ("Practical Meteorology," p. 169), tha problem of the dry- and wet-bulb thermometers is still quite open to fresh investig

Hygrometric Calculations.—Having found the dew-point of the air, usually required to deduce other data concerning the moistness of the air. necessary calculations are a little intricate, but have been brought to a very satisfa state of accuracy by Mr. Glaisher, whose excellent hygrometrical tables for the and wet-bulb thermometers, give all the necessary deductions from the readin the thermometers, almost without calculation. These tables are quite indispensab any person who has frequently to make hygrometrical calculations, but the inge hygrometric sliding rule of Mr. Welsh (Brit. Assoc. 1851; Trans. Sec. p. 42 manufactured by Adie, will also give most of the required results mechanically. can here only enter the subject briefly.

The elastic force of aqueous vapour in the air is the same as the maximum el force at the dew-point, and we, therefore, ascertain it by referring to the temper of the dew-point in a table of the maximum elastic force of vapour. The follo table (II.), having been calculated from the experimental results of Regnault, i most reliable of the kind.

If there be a fractional part of a degree over, multiply it into the next following *d ence* in the third column (dividing by 10 if a decimal), and add the result t number opposite the whole degree.

This table differs somewhat from that adopted by the Royal Society in "Report on Physics" (p. 89), and from several others calculated from older and trustworthy experiments than those of Regnault.

To find the weight of a cubic foot of aqueous vapour of maximum tension at temperature t, let E_t be the elastic force at that temperature. Then since 25 grains is the weight of a cubic foot of vapour at 212°, of an elastic force of 30 in 258·448 grains $\times \frac{E}{30}$ would be the weight of a cubic foot of the vapour saturate temperature t, after it has been heated up to 212° and kept under the same pre E_t as before. Since a gas expands 0·3665 of its own volume from 32° to 212 0·0020361 for each degree Fahr.,

$$258{\cdot}448 \text{ grains} \times \frac{E_t}{30} \times \frac{1{\cdot}3665}{1 + {\cdot}0020361 \times (t - 32°)}$$

will be the weight of a cubic foot of vapour saturated at the temperature t. From formula, the numbers in Table III. (p. 232), column 2, were obtained.

When the air is saturated with vapour and the temperature of the air of evapor and of the dew-point coincide, the required weight of vapour in a cubic foot of air

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lastic Force of Aqueous Vapour in inches of egree Fahr. from 0° to 100°.

Force of vapour. Inch mercury.	Differ-ence.	Tempera-ture. °F.	Force of vapour. Inch mercury.	Differ-ence.
·196		68	·684	
·204	8	69	·708	24
·212	8	70	·733	25
·220	8	71	·759	26
·229	9	72	·785	26
·238	9	73	·812	27
·247	9	74	·840	28
·257	10	75	·868	28
·267	10	76	·897	29
·277	10	77	·927	30
·288	11	78	·958	31
·299	11	79	·990	32
·311	12	80	1·023	33
·323	12	81	1·057	34
·335	12	82	1·092	35
·348	13	83	1·128	36
·361	13	84	1·165	37
·374	13	85	1·203	38
·388	14	86	1·242	39
·403	15	87	1·282	40
·418	15	88	1·323	41
·433	15	89	1·366	43
·449	16	90	1·410	44
·465	16	91	1·455	45
·482	17	92	1·501	46
·500	18	93	1·548	47
·518	18	94	1·596	48
·537	19	95	1·646	50
·556	19	96	1·697	51
·576	20	97	1·751	54
·596	20	98	1·806	55
·617	21	99	1·862	56
·639	22	100	1·918	56
·661	22			
	23			

ble. In all other cases, however, since vapour ther gas, we must have

$$\left.\begin{matrix}\text{cubic foot}\\ \text{dew-point}\end{matrix}\right\} \times \frac{\text{Volume at dew-point}}{\text{volume at temperature of air.}}$$

r is easily calculated from the following data of

$\frac{1}{13}$ or ·0020361 parts of its volume at 32° F. for

c foot of dry air at 32° under a pressure of 30 ains. Thus are calculated, for a pressure of olumn 3 of Table III.

foot of aqueous vapour of the same tempera- into a cubic foot of space, the elastic force of astic forces of the air and vapour. In order he same elastic force as the dry air previously, portion of the elastic force of the dry air to the vapour.

at temperature t,

air—say the atmospheric pressure as shown by

air,

$$\frac{\text{moist air}}{\text{dry air}} = \frac{p}{p - E_t}.$$

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TABLE III.

1	2	3	4	1	2	3	4
mpe-ature °F.	Weight of a cubic foot of saturated vapour. Grains.	Weight of a cubic foot of dry air. Grains.	Weight of a cubic foot of air saturated with vapour. Grains.	Tempe-rature. °F.	Weight of a cubic foot of saturated vapour. Grains.	Weight of a cubic foot of dry air. Grains.	Weight of a cubic foot of air saturated with vapour. Grains.
0	0·55	606·37	606·03	56	5·04	540·45	537·45
5	0·68	599·83	599·40	57	5·21	539·40	536·30
10	0·84	593·44	592·94	58	5·39	538·36	535·15
15	1·04	587·18	586·55	59	5·58	537·32	534·00
20	1·30	581·05	580·26	60	5·77	536·28	532·84
25	1·61	575·05	574·08	61	5·97	535·25	531·69
30	1·97	569·17	567·99	62	6·17	534·22	530·55
32	2·13	566·85	565·58	63	6 38	533·20	529·42
35	2·39	563·42	561·99	64	6·59	532·18	528·28
				65	6·81	531·17	527·14
40	2·86	557·77	556·03	66	7·04	530·16	526·01
41	2·97	556·66	554·86	67	7·27	529·15	524·86
42	3·08	555·55	553·69	68	7·51	528·14	523·71
43	3·20	554·44	552·52	69	7·76	527·14	522·56
44	3·32	553·34	551·35	70	8·01	526·15	521·41
45	3·44	552·24	550·19	71	8·27	525·16	520·27
46	3·56	551·15	549·02	72	8·54	524·17	519·12
47	3·69	550·06	547·85	73	8·82	523·18	517·98
48	3·82	548·97	546·69	74	9·10	522·20	516·83
49	3·96	547·89	545·53	75	9·39	521·22	515·69
50	4·10	546·81	544·37				
51	4·24	545·74	543·21	80	10·98	516·39	509·97
52	4·39	544·67	542·06	85	12·78	511·65	504·19
53	4·55	543·61	540·89	90	14·85	506·99	498·43
54	4·71	542·55	539·75	95	17·18	502·41	492·56
55	4·87	541·50	538·60	100	19·84	497·93	486·65

us one cubic foot of dry air, after becoming saturated with moisture, expands into the ume $\frac{1}{1-\frac{E_t}{p}}$ if it be confined under the same pressure as before.

We may now find the weight of a cubic foot of air saturated with aqueous vapour at y temperature: for it is obviously

Veight of cubic foot of dry air + weight of cubic foot of vapour) $\times \frac{p-E_t}{p}$.

Thus are obtained the numbers in column 4 of Table III. When the dry- and wet-lb thermometers read alike, we have at once the weight of a cubic foot of the nosphere for the barometric pressure of 30 inches. For any other height of the rometer we must multiply by this height in inches and divide by 30. When the r is not saturated, we must subtract the following:

$$\left\{\begin{matrix}\text{Weight of cub.}\\ \text{ft. of dry air}\end{matrix}\right\} - \left\{\begin{matrix}\text{weight of cub. ft.}\\ \text{of saturated air}\end{matrix}\right\} \times \frac{\text{Weight of cubic foot of vapour at dew-point}}{\text{Weight of cubic foot of vapour at temperature of air:}}$$

om the weight of a cubic foot of dry air, and reduce the result as before to the rometric pressure at the time.

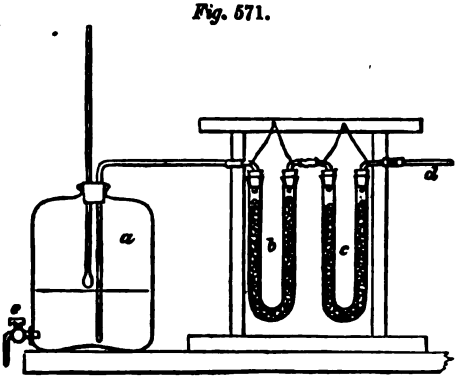
The Degree of Humidity represents the proportional saturation of the air with isture, decimally expressed, so that saturated air has the degree 100, and perfectly y air the degree 0. It is found by dividing the weight of vapour (Table III. lumn 2) at the dew-point by the weight which would be present at the temperature the air, if it were saturated. Some writers use the corresponding elastic forces of e vapours at the dew-point and temperature of the air (Table II.) in place of the ights of vapour, but the results are nearly the same.

Chemical Method of Hygrometry. The chemist may always avoid the fficulties attending the use of hygrometers, by absorbing the aqueous vapour from

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any given volume of air and actually weighing it upon the chemical balance. The necessary apparatus (*fig.* 671) consists of a common aspirator *a* and two U-shaped drying tubes *b*, *c*, containing fragments of pumice-stone soaked in strong sulphuric acid. The aspirator being full of water, the second tube *c* is detached, weighed accurately, and again attached on one side to the other drying tube *b*, on the other side to a long *perfectly dry* tube *d*, by means of which air from any required point, as for instance from the open atmosphere outside the laboratory window, may be drawn through the apparatus.

Fig. 671.



The fixed drying tube *b* is employed to prevent any vapour passing back from the aspirator. Regnault took great pains to ascertain the least necessary size of the weighed drying tube. He generally indeed employed two weighed tubes, each 0·18 metre in height, filled with *large* fragments of pumice-stone. But the second tube *rarely* gained 1 or 2 milligrammes in weight, and chiefly served to afford a proof that the absorption by the first tube was complete. It is probably best therefore to dispense with a second weighed tube, as the increased error in weighing the larger apparatus will probably be greater than the minute weight of vapour which may be lost. Additional accuracy may always be had by increasing the volume of air passed through the tube.

A determinate volume of water having been allowed to flow slowly and uniformly from the aspirator by the tap *e*, an equal volume of air, of course, passes through the tube *c*, and becomes desiccated. The weight of vapour absorbed is learnt by again weighing the tube *c*, but to determine the corresponding weight of air with accuracy, we must read the temperature at the end of the experiment by a thermometer placed in the centre of the aspirator, and likewise observe the barometer, then performing the calculation as directed on page 230.

This method may also be used to determine the amount of water *suspended* in the air in the form of mist or cloud. The weight of the watery particles is the excess of the whole weight absorbed over the maximum weight of vapour (saturated) as given in Table III. column 2.

The chemical determination of vapour has been fully considered by Brunner. (Ann. Ch. Phys. [3] iii. 309.)

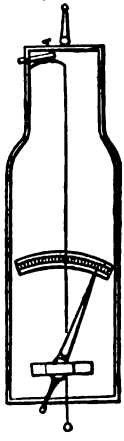
The chemical method might obviously be used to determine the average amount of vapour in the air during any period of time. It is only necessary for this purpose that a perfectly uniform stream of air pass through the drying tube throughout the period. The total weight of vapour absorbed, divided by the total weight of air passed through, gives the required result. Such a process was proposed by Dr. Andrews (Brit. Assoc. 1851, Trans. of Sec. p. 29), who has also described an aspirator suitable for the purpose (Phil. Mag. [4] iv. 330), and we know not why it is not adopted, at least in some of the principal observatories.

Hygroscopic bodies. Most organised structures expand or contract according to their state of moisture or dryness, and many organic substances to such a degree that they afford very delicate indications of hygrometric changes. Thus a thin shaving of whalebone laid on the hand instantly curls up, and a slip of whalebone furnished with a multiplying index formed the hygrometer finally adopted by Deluc (Phil. Trans. [1791] lxxxi. 419). An ivory hygrometer was also constructed by Deluc (Phil. Trans. [1773] p. 404) and Leslie (Ann. Ch. Ph. i. 468). A hygroscope formed of pieces of deal-wood was designed in 1676 by John Coniers (Phil. Trans. xi. 715). Chimney ornaments are often seen in which certain figures are caused to move by the contraction or expansion of catgut, thus indicating the approach of rain or fine weather. The awn of the *Andropagon contortum* has been used for similar purposes by Capt. Kater; the awn of the *Avena fatua*, or wild oat, by Hooke; the internal membrane of the *Arundo Phragmites*, or common reed, by Adie; and the *Funaria hygrometrica*, or common cord-moss, the arista of the seed of the *Stipa pennita*, or common feather-grass, by others. The hygroscope usually placed at the top of the common barometer or weather-glass consists of an awn or vegetable filament which in twisting or untwisting moves a light index.

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Saussure's Hair Hygrometer is the only instrument of this class which has been supposed in late years to possess any scientific accuracy or importance. To construct it, long, soft and straight human hairs must be procured and boiled for half an hour in a litre of water containing 10 grammes of crystallised carbonate of soda. After being well washed in pure water and dried without heat, the best hair is chosen, of a length of about 24 centimetres. One end is fixed to the top of the instrument (*fig.* 572), and the other, being passed round a pulley of the diameter of 6 millimetres, is attached to a weight of about 0·2 gramme (3 grains). An index fixed to the pulley moves over a divided circle, the divisions of which are determined by placing the instrument first over water and then over sulphuric acid, that is in perfectly moist and perfectly dry air, and dividing the space which the index is thus caused to move over into 100 equal parts. When well and delicately constructed, such an instrument will promptly show the slightest changes of moisture in the air.

Fig. 572.



Regnault, in his "Etudes de l'Hygrométrie," has spent much labour and ingenuity in trying to render the Hair Hygrometer scientifically useful. He has only succeeded in showing that two of these instruments will give very different results, if there exists the slightest difference in the nature of the hairs, their preparation, or the weight by which they are extended; that the most carefully constructed instruments are but little accordant; and that, after all, the degrees are quite arbitrary, and can only be reduced to true degrees of humidity or force of aqueous vapour, by a table specially determined by experiment for each instrument. Such a table may be found in Pouillet's *Elements de Physique*, 7th ed. ii. p. 742, having been prepared by Gay-Lussac, and supposed by him to apply to all Hair Hygrometers.

Regnault, indeed, has found that the zero of the Hair Hygrometer, at which it should stand in perfectly dry air, is quite illusory, for the hair will continue to shrink more or less even when it has been exposed for some months to the dry air. He therefore commences the graduation for air about ½ saturated, or of 20 degrees of humidity.

Kæmtz (*Météorologie*, Paris, 1858, p. 74) compares the table of Gay-Lussac with others calculated for Saussure's Hygrometer by Prinsep, Melloni, and August. There is very little accordance.

A great number of experiments on hygroscopes and hygroscopic substances are given in the three elaborate papers by Deluc in the Philosophical Transactions (1773 and 1791), and he says (Ph. Trans. [1791] lxxxi. 40), "I have concentrated in these pages an account of twenty years' assiduous labours in *hygrometry*, mostly occasioned by the anomalies of the *hygroscopic threads*."

There is a complete and learned history of hygrometry by Suerman, entitled "Commentatio de definiendâ Quantitate Vaporis aquei in Atmosphærâ," 4to. Lugd. Bat. 1831.

In Prof. Forbes' *Supplementary Report on Meteorology* (Brit. Assoc. Report, 1840. pp. 95–101) is an excellent *résumé* of the theory of the wet-bulb thermometer.

A general account of hygrometry, with examples of the calculations required in meteorology, is to be found in Dr. Drew's *Practical Meteorology*. W. S. J.

HYOCHOLALIC ACID. Syn. with Hyocholic Acid.

HYOCHOLIC ACID. $C^{36}H^{40}O^{4}$.—An acid obtained, together with glycocine, by the action of potash on hyoglycocholic acid. It is insoluble in water, soluble in alcohol and ether, and crystallises in mammellated granules. Its *barium-salt* dried at 180° contains $C^{36}H^{39}Ba''O^{6}$. (Strecker.)

HYOGLYCOCHOLIC ACID. $C^{37}H^{45}NO^{6}$. Formerly called *Hycocholic acid*. (Strecker and Gundelach, Ann. Ch. Pharm. lxii. 205.)—An acid which, in the form of a sodium-salt, constitutes the principal part of the bile of the pig: hence its name (from ὗς, ὑός a pig, and χολή bile).

To prepare the sodium-salt in the pure state, the fresh bile is completely saturated with sulphate of sodium; the mixture is heated for some hours on a sand-bath, and then left to cool; and the resulting precipitate, consisting of hyoglycocholate of sodium mixed with mucus and a small quantity of yellow colouring matter, is washed with a concentrated solution of sulphate of sodium, first by decantation and then on a filter, after which it is dried at 110° C. and treated with absolute alcohol, which dissolves the hyoglycocholate of sodium. The alcoholic solution is decolorised with animal charcoal, then precipitated by ether, and the precipitate is dried at 100°.

The free acid is obtained by precipitating the aqueous solution of the sodium-salt with dilute sulphuric acid, dissolving the precipitate in alcohol and precipitating with water. The liquid is milky at first, but becomes limpid after a while, and deposits

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ft on the sand-bath for several days, because the last traces of alcohol are evaporated. By repeat-s, the acid is obtained quite pure.

esinous body which melts in hot water, and then s after remaining for a few days over the water-of water; does not melt even at 120°. It is but g, however, an acid reaction; easily soluble in . It dissolves readily in *ammonia* and in dilute *carbonates*. According to F. Hoppe (Jahresber. he free acid exhibit an optical rotatory power oes not act on polarised light. It differs from the y its sparing solubility in water, and by forming h baryta, lime, &c.; in this respect it resembles

by dilute *sulphuric acid:* the concentrated acid urous acid. It is not oxidised by a mixture of but when the acid or any of its salts is heated ous fumes are evolved, and a yellowish mass is and cholesteric acids; at the same time volatile is with acetic acid. These volatile acids are yanic acid, when hyoglycocholic is oxidised by a *d sulphuric acid.*

ong time with strong *hydrochloric acid*, is decom-cocholic acid (ii. 900), yielding first a resinous holoïdic acid ?), then hyodyslysin insoluble in lution:

$$= C^{25}H^{35}O^{3} + C^{2}H^{5}NO^{2}$$

l. Hyodyslysin. Glycocine.

nation, yielding hyocholic acid, which differs from 1 at. water.

e, the *hyoglycocholates* in the dry state containing is obtained by adding chloride, carbonate, or ig's bile, or a solution of the sodium-salt. It ery sparingly in strong solutions of ammoniacal-The *barium-salt*, $C^{54}H^{84}Ba''N^{2}O^{10}.2H^{2}O$, dissolves n alcohol. The *calcium-salt*, $C^{54}H^{84}Ca''N^{2}O^{10}.2H^{2}O$, *d-salt* is a white precipitate obtained by mixing a eutral acetate of lead. This mother-liquor yields pitate which appears to be a basic salt.

$H^{2}O$, is prepared by dissolving the acid in caustic h sulphate of potassium, &c., as in the preparation orphous mass, which melts at the heat of the water-ohol; when quite dry, it remains solid even at 120°. a gelatinous precipitate, which becomes flocculent

$H^{2}O$, is a white powder which does not become lcoholic solution yields by evaporation a perfectly and very persistent taste. Heated on platinum-ith a smoky flame.

he resinous substance formed previous to hyodys-boiled with strong hydrochloric acid, is perhaps $^{4}H^{38}O^{4}$. According to Hoppe (Jahresber. 1858, otatory power = 23·6°.

-A substance homologous with dyslysin, produced by chloric acid on hyoglycocholic acid. It is insoluble ngly soluble in boiling alcohol, moderately soluble

nd Hesse, [1833] Ann. Ch. Pharm. vii. 270.)—An *cyamus niger*), and other species of Hyoscyamus. henbane are exhausted with hot alcohol containing expressed juice is mixed with a quantity of slaked alkaline reaction; the filtered liquid is slightly nd again filtered; the alcohol is distilled off to one-ter; and the rest of the alcohol driven off at the e remaining liquid is then cautiously added a con-

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centrated solution of carbonate of potassium, the liquid being again filtered if turbidity is thereby produced; then a large excess of the same solution; and the wh is shaken with ether as long as that liquid takes anything up. The ethereal solut separated from the watery liquid and evaporated, leaves impure hyoscyamine, wh may be purified by mixing it with water till a clear solution is produced; adding this solution twice its weight of ether-alcohol, digesting with animal charcoal, and e porating off the ether-alcohol, first at a gentle heat, and afterwards in vacuo. If residue is still coloured, it must be once more dissolved in dilute acid; the solut mixed with an equal quantity of alcohol, digested with animal charcoal, and decompo by excess of carbonate of potassium; the hyoscyamine extracted by ether; and whole process repeated if necessary.

Hyoscyamine may also be prepared, though less advantageously, from the h of the plant, while in flower, by boiling the expressed juice, filtering, mixing w lime, treating the filtrate with excess of carbonate of potassium, and dissolving out hyoscyamine by agitation with ether. The dried herb likewise yields it when trea with acidulated alcohol.

Hyoscyamine crystallises in stellate groups of silky needles, but is frequently a obtained as an amorphous sticky mass. When perfectly dry it is inodorous, but in moist state, it has an unpleasant odour resembling that of tobacco. It is soluble *water, alcohol,* and *ether*. The aqueous solution has an alkaline reaction. It me when heated, and then volatilises with partial decomposition. It is decomposed wh heated with *acids*. Strong *nitric acid* dissolves it without colour; strong *sulphu acid* turns it brown. *Iodine* added to its aqueous solution forms a copious precipit having the colour of kermes. Taken internally, even in small doses, it acts a narcotic poison. Rubbed into the eye, even in minute quantity, it produces persist dilatation of the pupil.

Hyoscyamine neutralises acids completely. Many of its salts crystallise and are p manent in the air. They have no odour, but an acrid, nauseous taste, and are v poisonous. Their solutions are not precipitated by dichloride of platinum; but yi whitish flocks with chloride of gold. With infusion of galls they form a white pre pitate.

HYPARGYRITE. See MIARGYRITE.

HYPERSPIROÏLIC ACID. Syn. with SALICYLIC ACID.

HYPER, as a prefix, syn. with PER.

HYPERSTHENE (from *ὑπέρ* and *σθένος*, strength, on account of the grea hardness and density of this mineral as compared with hornblende, with which it w formerly confounded). It is a sub-species of augite, containing, according to Mui analyses (Pogg. Ann. lxiv. 162),

SiO^2	Al^2O^3	CaO	MgO	FeO	MnO	H^2O
51·35	. .	1·83	11·09	33·92	. .	0·50 = 98·69

It is distinguished from common augite and diallage by its small proportion of calci and large proportion of iron, and may be represented by the formula $(Mg; Fe)^2SiO$

Hypersthene has a density of 3·3—3·6, and a greyish or greenish-black colour, w a more or less distinct copper-red metallic iridescence on the most distinct cleava surface, arising from the presence of microscopic laminæ of titaniferous iron imbedd in the mineral. It is remarkable that all the augitic rocks of Sweden contain titani rous iron.

The name *Paulite* is given to hypersthene found in the island of St. Paul on the coast Labrador. *Gedrite* is hypersthene in which the quantity of iron attains its maximu

HYPERSTHENITE or *Hypersthene-rock* is a crystallo-granular mixture hypersthene and labrador, with small quantities of titaniferous iron imbedded in t hypersthene, and occasional admixture of iron pyrites, mica, hornblende, olivine, garn opalite, &c. Labrador is usually the chief component. Quartz is never found in th rock. Hypersthene-rock belongs to the less frequently occurring crystalline, unstra fied formations. It is found in the island of St. Paul, on the coast of Labrador, Elfdalen in Sweden, at several localities in Norway, in the Isle of Skye, in Cornwall, the Harz in Silesia, Bohemia, &c.

The following analyses of hypersthenite are by Bunsen (Jahresb. 1861, p. 1070 *a*. Coarse-grained, containing brown hypersthene and greyish-white labradorite, fr a vein near Penig in Saxony.—*b*. Medium-grained, greenish-brown, containing greenis white labradorite and dark green augite, from Tabor, near Getschin in Bohemia.— *c*. Somewhat finer-grained and browner, from Stransko near Liebstadl.—*d*. Greyis green, crystalline, medium-grained, very slightly magnetic, containing triclinic felsp from Hrabacow near Starkenbach.—*e*. From the railway cutting of the Woleschka valle between Semil and Kostialow near Poric. It is finely crystalline, dark grey to greenis

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and effervesces with acids, in consequence of small masses of calcspar disseminated through it; scarcely magnetic, and with a weathered crust:

	SiO^2	Al^2O^3	Fe^2O^3	CaO	MgO	K^2O	Na^2O	H^2O
a.	49·90	16·04	7·81	14·49	10·08	0·55	1·68	1·46 = 102·01
b.	49·97							
c.	56·20	15·26	13·40	9·50	3·21			
d.	51·98	16·27	13·53	7·34	5·85	3·30	1·20	2·71 = 102·18
e.	54·44	18·06	9·64					

HYPOBROMOUS ACID. BrHO.—The formation of bleaching liquids analogous to the hypochlorites by the action of bromine on solutions of the alkalis and alkaline earths was noticed by Balard in his original memoir on bromine (Ann. Ch. Phys. [2] xxxii. 337), and subsequently by Löwig (Pogg. Ann. xiv. 14, 485), Fritzsche (J. pr. Chem. xxiv. 294), and Gay-Lussac (Compt. rend. xiv. 951). Balard also found that bromine-water forms with mercuric oxide a sparingly soluble oxybromide of mercury and a bleaching liquid which, by distillation in a vacuum, yields a liquid also possessing bleaching properties, and supposed to be hypobromous acid (i. 679).

More recently, Spiller (Jahresber. 1859, 97; 1862, 73) and Dancer (Chem. Soc. J. xv. 447) have shown that when bromine is added to excess of solution of nitrate of silver, half the bromine is precipitated as bromide of silver, while the other half remains in solution as hypobromous acid, forming a strongly bleaching liquid, from which, according to Dancer, the hypobromous acid may be distilled under a pressure of 50 mm. of mercury, the liquid then boiling at 50°. The distillate, which does not contain free bromine, is straw-yellow, has an acid reaction, bleaches strongly, and decomposes when heated above 60°. It gave by analysis numbers corresponding with the formula of hypobromous acid.

Hypobromous acid is likewise obtained in solution by agitating bromine-water with excess of mercuric oxide or oxide of silver. When bromine is brought in contact with excess of dry mercuric oxide, the mixture becomes very hot. By heating the two substances together in a sealed tube to 100° a powder is obtained which smells like chloride of lime and bleaches when moistened with water; it is a mixture of mercuric oromide, oxide and hypobromite. If the bromine is in excess, a solid mass is formed consisting merely of mercuric bromide and oxide. Oxygen is set free in both cases. (Dancer.)

All attempts to prepare hypobromous anhydride by methods similar to those which yield hypochlorous anhydride (i. 908) were unsuccessful, the compound being decomposed, both at common temperatures and at −18°, into bromine and oxygen.

HYPOCHLORIC ACID. Syn. with Perchloric oxide. (See CHLORINE, OXIDES OF, i. 912.)

HYPOCHLORITE. (*Grüne Eisenerde.*)—A mineral occurring at Schneeberg, Johanngeorgenstadt, and Bräunsdorf in Saxony, in minute greenish crystals and grains, or massive and earthy. It contains, according to Schüler's analysis, 50·24 per cent. silica, 14·65 alumina, 13·03 oxide of bismuth, 10·54 protoxide of iron, and 9·62 phosphoric anhydride, with a trace of manganese, and is perhaps a silicate of bismuth and iron mixed with phosphate of aluminium. (Dana, ii. 182.)

HYPOCHLORITES. ClMO.—The formation, general properties and reactions of these salts, and the methods of estimating the quantity of available chlorine contained in them, have been already described under CHLORINE (i. 904, 908). For the preparation of hypochlorite of calcium, its uses as a bleaching and disinfecting agent, and the methods of estimating its commercial value, see *Ure's Dictionary of Arts*, &c. 904; also *Richardson and Watts's Chemical Technology*, vol. i. pt. 3, pp. 360–425.

A sample of "chloride of lime," analysed by F. Rose under the direction of Fresenius (Ann. Ch. Pharm. cxviii. 317), yielded 26·72 per cent. $CaCl^2O^2$, 25·51 $CaCl^2$, 23·05 CaO, and 24·72 combined and hygroscopic water. On repeatedly triturating it with fresh quantities of water to a thin pulp, the chloride of calcium was found to dissolve at the first trituration, the hypochlorite only at the third. Hence Fresenius concludes that the two salts exist in the bleaching powder merely in a state of mixture, or at most as a loose combination easily decomposed by water. He regards bleaching powder as a mixture of hypochlorite and basic chloride or oxychloride of calcium, $CaCl^2O^2 + (CaCl^2.2CaO) + 4H^2O$. The basic chloride is resolved by water into chloride and hydrate of calcium.

Solutions of the hypochlorites of the alkali-metals have long been used as disinfecting agents. The so-called chloride of soda or Labarraque's disinfecting liquid, is a mixture of hypochlorite and chloride of sodium, prepared by passing chlorine into a solution of caustic soda or carbonate of sodium, or by decomposing hypochlorite of calcium (bleaching powder) with carbonate or sulphate of sodium. In the first mode of preparation, about 40 lbs. of soda-crystals are dissolved in about 20

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gallons of water, and a stream of chlorine is passed through the solution till it h attained a specific gravity of 1·06. A rise of the density above this point indicates t formation of chlorate of sodium. To prepare the disinfecting liquid by the secon method, about 20 lbs. of good bleaching powder are dissolved in about 26 gallons water, and to the filtered liquid is added a solution of 40 lbs. soda-crystals in abou 9 gallons of warm water. The filtered solution constitutes Labarraque's liquid.

Chloride of Potash or *Eau de Javelle* is a mixture of hypochlorite and chlorid of potassium prepared by similar methods.

A mixture of *hypochlorite of magnesium*, prepared by decomposing chloride lime with an equivalent quantity of sulphate of magnesium, is said by Claussen to more efficacious than other chlorine-compounds for bleaching flax and hemp.

Hypochlorite of Aluminium, prepared by mixing equivalent quantities of sulphate aluminium and hypochlorite of calcium, is recommended by Orioli (Rep. Pat. In April 1860) as a bleaching and antiseptic agent. It is very easily decomposed, an therefore acts very rapidly on organic matters. It may also be used as a mordan instead of acetate of aluminium, all the hypochlorous acid being disengaged at th heat of the dye-bath while the alumina remains attached to the fibre.

Hypochlorite of Zinc is also used as a mordant, and is recommended by Varrentrap (Dingl. pol. J. clviii. 378), on account of its ready decomposibility, as a bleachin agent. The action of chloride of lime may be advantageously accelerated by th addition of chloride of zinc instead of a mineral acid.

HYPOCHLOROUS ACID and **ANHYDRIDE** (i. 908).—This gas is absorbe by sulphuric anhydride, and when the latter compound, in a state of perfect drynes and in quantities of not more than 5 or 6 grms. at a time, is saturated with hypochlorou anhydride, a dark-red thickish liquid is formed, which solidifies on cooling to a mass light red needles apparently consisting of $Cl^2O.4SO^3$. These crystals melt at 55°, an detonate when suddenly raised to a higher temperature. They are instantly decom posed by water into sulphuric and hypochlorous acids; hence the compound acts a a powerful oxidising agent on sugar, alcohol, and other organic substances. Iodin decomposes it, with evolution of chlorine and formation of iodic acid.

When hypochlorous anhydride is passed into liquid sulphurous anhydride, a ver brisk reaction takes place as soon as the containing vessel is removed from the freezin mixture, chlorine being evolved and a red viscid substance remaining, composed sulphuric and hypochlorous anhydrides in a proportion not yet determined. (Schütz enberger, Compt. rend. lii. 135; liii. 538; Jahresber. 1861, p. 142.)

HYPOGÆIC ACID. $C^{16}H^{30}O^2 = \left.\begin{matrix} C^{16}H^{30}O \\ H \end{matrix}\right\}O$.—An acid belonging to the olei series $C^nH^{2n-2}O^2$, discovered in 1855 by Gössmann and Scheven (Ann. Ch. Pharm xciv. 230) in oil of earthnut (*Arachis hypogæa*) It is isomeric, if not identical, wit physetoleic acid, discovered in 1844 by Hofstädter (Ann. Ch. Pharm. xci. 177) i sperm-oil (see PHYSETOLEIC ACID), also with the acid obtained by oxidation of axini acid ($C^{18}H^{28}O^2$), an acid produced by the saponification of the fatty substance, age o axin, contained in the Mexican plant, *Coccus Axin*. (F. Hoppe, J. pr. Chem. lxxx 102.)

Preparation from Earth-nut oil.—The fatty acids of the oil are dissolved in alcohol arachidic and palmitic acids are precipitated by ammonia and acetate of magnesium the precipitate is removed; and the filtrate is mixed with ammonia and an alcoholi solution of neutral acetate of lead. The precipitate is collected after a few days, pressed and dissolved in ether; the ethereal solution is agitated with aqueous hydrochlori acid; the chloride of lead is filtered off; the filtrate is shaken up with water which ha been freed from air by boiling; the ethereal layer which separates again on leavin the liquid at rest is taken off; and the ether is removed by distillation. The remainin liquid on cooling deposits yellowish crystals, which may be purified by pressure an recrystallisation from alcohol at a very low temperature. An additional quantity o crystals may be obtained from the mother-liquor. (Gössmann and Scheven.)

Axinic acid yields by oxidation, aginin insoluble in ether, and the acid, $C^{16}H^{30}O^2$ which may be dissolved out by ether, and crystallises from the ethereal solution.

Hypogæic acid crystallises in stellate groups of needles, inodorous, melting at 34° o 35° (physetoleic acid melts at 30° and solidifies at 28°), easily soluble in alcohol an in ether.—1. When exposed to the air, it acquires a yellowish colour and rancid odour and then crystallises with difficulty, even at very low temperatures.—2. Whe subjected to dry distillation, it first gives off a reddish-yellow liquid, then yellowish white crystalline sebacic acid, and lastly, a fetid oil, leaving a small quantity of char coal.

Nitrous acid converts hypogæic acid into the isomeric compound gaïdic acid, whic is related to it in the same manner as elaïdic to oleic acid. It forms a colourless crys talline mass, permanent in the air, melting at 38°, solidifying in the radio-crystallin

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form on cooling, and volatilising undecomposed at higher temperatures. (Caldwell and Gössmann, Ann. Ch. Pharm. xcix. 305.)

Hypogæic acid is monobasic. The *barium-salt* is obtained by adding alcoholic acetate of barium to an alcoholic solution of the acid mixed with excess of ammonia, in white grains which dissolve when heated and separate again on cooling.

Hypogæate of Copper, $C^{32}H^{30}Cu''O^4$, is obtained, in like manner, by mixing alcoholic cupric acetate with a hot alcoholic solution of the acid containing ammonia, and separates on cooling in violet-blue crystalline grains, soluble in alcohol and cohering to a translucent wax at 75°.—*Gaïdate of copper* is obtained by mixing aqueous gaïdate of sodium with cupric sulphate, as a scarcely crystalline precipitate, which dissolves with difficulty in alcohol, and separates therefrom in granules. It melts without decomposition at a temperature above 120°.

Hypogæate of Ethyl, $C^{16}H^{29}(C^2H^5)O^2$, is obtained by passing hydrochloric acid gas through a solution of hypogæic acid in alcohol of 95 per cent. and separates on warming the liquid, as an oil which may be freed from adhering acid by washing with small quantities of alcohol, and dried in a stream of carbonic anhydride between 100° and 120°. It is yellow, inodorous, lighter than water, but sinks in alcohol, in which it is but slightly soluble. Not volatile without decomposition.

Gaïdate of Ethyl is prepared by passing hydrochloric acid gas through a solution of gaïdic acid in absolute alcohol, precipitating after 12 hours with water, and subjecting the separated mixture of gaïdic ether and gaïdic acid to a second treatment with hydrochloric acid. The product is washed and dried at 100° in a stream of hydrogen. It is a colourless, lamino-crystalline mass, which melts between 9° and 10°, and volatilises undecomposed at a higher temperature. It is inodorous, lighter than water, heavier than alcohol, and sparingly soluble in alcohol.

Gaïdate of Silver is obtained by precipitation as a white amorphous mass which, when washed, and especially if heated with water, alcohol or ether, turns black without dissolving.

Gaïdate of Sodium is obtained by dissolving the acid in aqueous carbonate of sodium, evaporating, and exhausting the residue with absolute alcohol; the solution on cooling deposits the salt as a translucent jelly: from dilute solutions it separates in crystalline grains.

HYPOGALLIC ACID. $C^7H^6O^4$. (Matthiessen and Foster, Chem. Soc. J. xvi. 360.)—An acid produced by the action of boiling concentrated hydriodic acid on hemipinic acid (p. 142):

$$\underset{\text{Hemipinic acid.}}{C^{10}H^{10}O^6} + 2HI = \underset{\text{Hypogallic acid.}}{C^7H^6O^4} + \underset{\text{Iodide of methyl.}}{2CH^3I} + CO^2.$$

It is isomeric with carbohydroquinonic, protocatechuic and oxysalicylic acids, and intermediate in composition between salicylic acid, $C^7H^6O^3$, and gallic acid, $C^7H^6O^5$.

Hypogallic acid, when pure, is only slightly soluble in cold water, but dissolves easily in hot water, alcohol, and ether; its solution reacts strongly acid with litmus-paper. It separates from hot water in small prismatic crystals, united into stellate groups, and containing $1\frac{1}{2}$ at. water of crystallisation, which they lose at 100°. The acid melts at about 180°, but as it begins to decompose even at a lower temperature, its melting-point could not be accurately ascertained.

Hypogallic acid gradually turns brown when heated in the air to a little above 100°; the same change occurs more quickly when a solution of it, especially if neutral or alkaline, is evaporated. Added to solution of *nitrate* or *ammonio-nitrate of silver*, it causes an immediate precipitation of metallic silver, even in the cold; with *sulphate of copper* and a slight excess of potash, it gives a yellowish green solution, from which an orange-yellow precipitate is thrown down on warming; in a mixture of *sesquichloride of iron and red prussiate of potash*, it immediately produces a blue precipitate; when boiled with solution of *mercuric chloride*, it reduces it to calomel. With *sesquichloride of iron*, it gives an intense indigo-blue coloration, which is changed to violet by a very small quantity of ammonia, and to blood-red by excess of ammonia, no precipitate being produced, unless too much chloride of iron has been used; the colour is destroyed by strong acids, but restored by neutralisation with alkali, and partially by addition of water. A solution of the acid immediately becomes brown on addition of *alkali*, the colour quickly becoming darker by exposure to the air. With *ammonia and chloride of barium* or *calcium*, it gives a brownish white flocculent precipitate; with *acetate of lead*, a pale yellow precipitate.

Hypogallic acid is decomposed by heat into carbonic anhydride and a substance which solidifies in the neck of the retort to a colourless crystalline mass. The decomposition begins at about 170°, and goes on rapidly at 200°. The crystalline product melts, in the crude state, at about 90°; it dissolves easily in water, and crystallises in needles when the solution is evaporated. It is rapidly attacked by nitric

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acid, even when diluted, giving a red-brown solution. With sesquichloride of i gives a bluish-black amorphous precipitate; with acetate of lead it gives a wh yellowish-white precipitate, soluble in an excess of acetic acid. It slowly assu darker colour by exposure to air in contact with alkali. This substance has n been prepared in sufficient quantity for complete investigation.

The three acids above mentioned as isomeric with hypogallic acid, have abou same solubility in water, alcohol, and ether, as the latter; they all likewise give a coloration with the smallest trace of sesquichloride of iron; reduce nitrate of si become dark brown when mixed with alkali and exposed to the air; give a yello white precipitate with acetate of lead; and at a high temperature are all decom into carbonic anhydride and oxyphenic acid or hydroquinone. Nevertheless, n of these acids appear to have quite the same properties. The following are the important points in which differences have been observed. Hypogallic acid crysta with $1\frac{1}{2}$ molecule of water (14·9 per cent.), carbohydroquinonic and protocatechuic with 1 molecule (10·4 per cent.), and oxysalicylic acid without water. Hypogalli oxysalicylic acids give a dark-blue colour with sesquichloride of iron, the othe acids a dark-green colour. Hypogallic acid reduces nitrate of silver immediat the cold; carbohydroquinonic acid reduces it slowly in the cold, rapidly when b oxysalicylic acid has no action on nitrate of silver in the cold, but reduces it comp when boiled. Carbohydroquinonic acid reduces cuprous oxide from a mixture of acetate, tartaric acid, and excess of potash; protocatechuic acid causes no reducti the same solution. Hypogallic acid causes a precipitate in a mixture of chlori barium and ammonia; protocatechuic acid only on addition of alcohol. Some of differences may perhaps be due to accidental causes, depending on the different so and modes of preparation.

HYPO-IODIC ACID. See IODINE, OXACIDS OF.

HYPONIOBIC ACID. See NIOBIUM.

HYPONITRIC ACID. Syn. with Pernitric oxide. (See NITROGEN, OXIDE

HYPONITROMECONIC ACID. Syn. with Nitromeconin. (See MECO

HYPONITROUS ACID. Syn. with NITROUS ACID.

HYPOPHOSPHOROUS ACID. See PHOSPHORUS, OXYGEN-ACIDS OF.

HYPOSCLERITE. A name applied by Breithaupt to a mineral from Ar which, according to Rammelsberg, is probably albite mixed with augite. (See A under FELSPAR.)

HYPOSTILBITE. Syn. with STILBITE.

HYPOSULPHAMYLIC ACID. Syn. with Amyl-sulphurous acid. (See PHUROUS ETHERS.)

HYPOSULPHARSENIOUS ACID. Syn. with Disulphide of Arsenic. ARSENIC, SULPHIDES OF, i. 386.)

HYPOSULPHETHYLIC ACID. Syn. with Ethyl-sulphurous acid. SULPHUROUS ETHERS.)

HYPOSULPHINDIGOTIC ACID. } See INDIGO-SULPHURIC ACIDS.
HYPOSULPHOCERULIC ACID. }

HYPOSULPHOGLUTIC ACID. Syn. with SULPHOGLUTIC ACID.

HYPOSULPHOMETHYLIC ACID. Syn. with Methyl-sulphurous acid. SULPHUROUS ETHERS.)

HYPOSULPHONAPHTHALIC and **HYPOSULPHONAPHTHI ACIDS.** See SULPHONAPHTHALIC ACIDS.

HYPOSULPHOPHOSPHORIC and **HYPOSULPHOPHOSPHOR ACIDS.** See PHOSPHORUS, SULPHIDES OF.

HYPOSULPHURIC and **HYPOSULPHUROUS ACIDS.** See SUL OXYGEN-ACIDS OF.

HYPOVANADIC ACID. See VANADIUM.

HYPOXANTHINE. An azotised organic substance discovered by Sch (Ann. Ch. Pharm. lxxiii. 328) in the spleen of man and in the ox, and since fou exist in many other parts of the animal body. It is probably identical with SA (*q.v.*)

HYSSOPINE. A doubtful alkaloïd, said by Herberger to exist in the he *Hyssopus officinalis*.

HYSSOP, OIL OF. A volatile oil obtained from *Hyssopus officinali*

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distillation with water. It is yellow when fresh, but turns red by keeping; has a sharp taste and smells like camphor.

HYSTATITE. Syn. with ILMENITE.

I

IASPACHATES. A variety of agate.

IDERITE. A silicate from Montoval, near Toledo, occurring in large six-sided prisms with basal cleavage. Hardness = 2·5. Specific gravity = 2·89. Contains, according to Norlin (Kongl. Vetensk. Akad. Förhandlingar, 1844, 215), 40·90 per cent. SiO^2, 30·74 Al^2O^3, 15·47 FeO, MnO 1·33, 0·40 CaO, 0·81 MgO, 4·57 K^2O, 0·04 Na^2O, 5·56 H^2O = 99·82. Fuses to a dark pearl before the blowpipe. It is probably allied to dichroïte.

ICE-SPAR. A name sometimes applied to a transparent variety of felspar found in Vesuvian lavas: the term includes pellucid varieties of other species of felspar. (Dana.)

ICELAND-SPAR. Transparent calc-spar. (See CALC-SPAR.)

ICHTHIDIN. A substance contained in the immature eggs of cyprinoïd fishes.

ICHTHIN. The azotised constituent of the eggs of cartilaginous fishes. It is easily extracted from the eggs of the ray by pouring the yolk into a large quantity of distilled water, washing the dense granules which fall to the bottom till the wash-water contains only traces of albumin and saline matters, and finally exhausting them with alcohol and ether.

Ichthin thus obtained forms homogeneous, white, transparent grains, soft to the touch, insoluble in water, alcohol, and ether. Hydrochloric acid dissolves it without violet coloration; it is also readily soluble in dilute acetic and phosphoric acid, and in other acids in the concentrated state. Solutions of potash and soda dissolve it slowly; ammonia does not act upon it. It gives by analysis 50·2 to 51·0 per cent. carbon, 6·7 to 7·8 hydrogen, 14·7 to 15·4 nitrogen, and 1·9 phosphorus (?). It does not appear to contain sulphur. It leaves but a trace of ash when burnt. (Valenciennes and Frémy, Compt. rend. xxxviii. 480, 528.)

ICHTHULIN. The very young eggs of cyprinoïd fishes contain, besides icthidin, a strongly albuminous liquid which holds in suspension certain mineral salts, together with ichthulin, which may be precipitated by water. When first precipitated, it is viscid like gluten; but when treated with alcohol and ether, it loses its viscosity and becomes solid and pulverulent. Like ichthin, it dissolves in acetic and in phosphoric acid, also in hydrochloric acid, without violet coloration. It contains 52·5 to 53·3 per cent. carbon, 8·0 to 8·3 hydrogen, 15·2 nitrogen, 1·0 sulphur, and 0·6 phosphorus (?). It seems to disappear as the eggs approach maturity, and to be replaced by albumin. (Valenciennes and Frémy.)

ICHTHYOCOLL or **ISINGLASS.** See GELATIN (ii. 826).

ICHTHYOPHTHALMITE. Syn. with APOPHYLLITE (i. 351).

ICICA-RESIN. A resin very similar to elemi, obtained from trees very common in Guiana, belonging to the order *Terebinthaceæ*. It occurs in small masses or opaque grains, having a yellowish-white colour, and a sweet, rather agreeable odour, the strength of which is increased by heat. It is friable and tasteless. It gives up nothing to water, and is but sparingly soluble in alcohol, requiring for complete solution 45 parts of cold alcohol of 36°, and 15 parts of boiling alcohol; it dissolves also in 3½ parts of oil of turpentine at ordinary temperatures. It is insoluble in alkalis. Its alcoholic solution does not precipitate lead or silver salts.

Icica-resin is composed of three distinct substances, separable by their different degrees of solubility in alcohol.

a. If the resin be completely dissolved in boiling alcohol, one of these substances, viz. brean, crystallises on cooling. It has the composition of cholesterin, and forms white, tasteless, needle-shaped crystals, insoluble in water and in alkalis, sparingly soluble in alcohol, and having a neutral reaction. It melts at 137°, and solidifies on cooling to a mass resembling amber. By dry distillation it yields empyreumatic oils, a volatile, solid, amorphous substance which collects in the neck of the retort, and a small residue of charcoal. It is dissolved, with red colour, by sulphuric acid, and precipitated unaltered by water. Nitric acid decomposes it, with evolution of nitrous fumes, forming a yellow body soluble in excess of nitric acid, and precipitated on addition of water.

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b. On removing the brean and concentrating the mother-liquor, a certain quantity of the same substance, in an impure state, first separates, and afterwards another crystalline resin, icican, which has the same melting-point as brean, and resembles it in most of its other properties, but is distinguished by its greater solubility in alcohol. It gives by analysis 82·01 per cent. C, 11·65 H, and 6·34 O, which may be represented by the formula $C^{20}H^{34}O$. Its composition is about the same as that of the resin of *Ceroxylon Andicola*.

c. The mother-liquor of icican, after being completely freed from crystallisable matter, deposits a small quantity of a yellow amorphous resin, which melts below 100°, and is much more soluble in alcohol and ether than brean or icican. Its alcoholic solution is slightly acid to test-paper, but the resin does not dissolve in alkalis. It contains 77·93 per cent. C, 10·69 H, and 11·47 O, corresponding approximately with the formula $C^{20}H^{30}O^2$. (Scribe, Ann. Ch. Phys. [3] xiii. 166.)

IDIOTYPE. A term applied by Guthrie (Chem. Soc. J. xiii. 35) to bodies derived by replacement from the same substance, including the typical substance itself; ammonia, for example, is idiotypic with ethylamine, phenylamine, and all the organic basis derived from it by substitution, and these are idiotypic one with the other.

The same term was applied by Wackenroder (J. pr. Chem. xxiv. 18) to certain non-crystalline organic bodies which, according to his observations, exhibit certain similarities of structure.

IDOCRASE. See Vesuvian.

IDRIALIN. $C^{42}H^{28}O$ (?).—The essential constituent of idrialite, from which it is obtained either by dry distillation in an atmosphere of carbonic anhydride—or better, by boiling the mineral with rock-oil or oil of turpentine; the liquid on cooling solidifies in a mass, which may be freed from the solvent by means of bibulous paper.

Idrialin forms colourless scales, which melt at a very high temperature, with partial decomposition. When distilled, it partly volatilises, but at least $\frac{9}{10}$ of it is decomposed at the same time, even in an atmosphere of carbonic anhydride. It is insoluble in *water*, even at the boiling heat, and nearly insoluble in *alcohol* and *ether;* the best solvent for it is boiling *oil of turpentine*. It gives by analysis 91·7 to 92·0 per cent. carbon, and 5·1 to 5·4 hydrogen, agreeing nearly with the formula above given—which requires 91·07 C, 5·11 H, and 2·92 O. (Bödeker, Ann. Ch. Pharm. lii. 100.) Dumas and Laurent regarded it as a hydrocarbon $C^{15}H^{10}$, but these results were calculated according to the old atomic weight of carbon.

Idrialin heated with strong *sulphuric acid* forms a solution of a fine blue colour, like that of sulphindigotic acid. The solution diluted with water forms with bases peculiar salts, among which the potassium-salt is distinguished by its beautiful crystalline character.—Idrialin boiled with strong *nitric acid* yields a red powder (Laurent's *nitrite of idrialase*) destitute of taste and odour, insoluble in water and ether, soluble in sulphuric acid, to which it imparts a mahogany colour. In potash it dissolves with brown colour. Heated in a closed tube, it decomposes with explosion and emission of light. According to Laurent's analysis, it contains 62·7 to 63·3 per cent. carbon, 3·2 to 3·0 hydrogen, and 10·5 nitrogen, approximating to the formula $C^{42}H^{23}(NO^2)^3O$. (65·2 C, 2·9 H, and 9·0 N).

IDRIALITE. The mineral from which idrialin is obtained. It is found in the quicksilver mine of Idria, mixed with cinnabar, and is sometimes called *inflammable cinnabar* (*Quecksilberbranderz*). It is massive and opaque, with greasy lustre, greyish or brownish-black colour, and blackish streak inclining to red. Specific gravity, 1·4 to 1·6. Hardness, 1 to 1·5.

IDRYL. Bödeker found in a product obtained by the dry distillation of the quicksilver ore of Idria in a close vessel, two peculiar hydrocarbons, one of which (*idryl*) formed mammellated groups, fusible at 86°, volatile without decomposition, very soluble in alcohol, ether, acetic acid, and oil of turpentine; while the other formed scales melting above 100°, volatilising before melting, and much more soluble than the former. Their composition agreed nearly with the formula, nC^3H^2 (94·7 C and 5·3 H).

IGASURIC ACID. Pelletier and Caventou (Ann. Ch. Phys. [2], x. 142). An acid contained, in very small quantity, combined with strychnine, in the bean of St. Ignatius; also in *nux vomica*, and in the root of *Strychnos colubrina*. It is prepared by washing the magnesia which has served for the preparation of strychnine, with cold water, till the colouring matter is removed, then boiling it with a large quantity of distilled water, which dissolves the igasurate of magnesium, precipitating it with acetate of lead, decomposing with sulphydric acid, and evaporating to a syrup. The acid is then deposited, after a while, in small hard granular crystals. It has a sour, styptic taste, and is very soluble in water and in alcohol. Corriol regards it as identical with lactic acid; but, according to Marsson (Ann. Ch. Pharm. lxxii. 296), this identity does not exist, for igasuric acid precipitates acetate of lead, which lactic acid does not.

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The *igasurates* are for the most part soluble in water and in alcohol. The *ammonium-salt* is perfectly neutral, does not precipitate the salts of iron, mercury, or silver, but colours copper-salts green, and then forms a greenish-white precipitate sparingly soluble in water.

IGASURINE. An alkaloïd, discovered in 1853 by Desnoix (J. Pharm. [3], xxv. 202). It exists in *nux vomica*, and is found in the mother-liquors from which strychnine and brucine have been precipitated by lime at the boiling heat. These mother-liquors, if sufficiently concentrated, deposit the igasurine in crystals on the sides of the vessel. It may be purified by dissolving in water acidulated with hydrochloric acid, treating the solution with animal charcoal, precipitating by ammonia, and recrystallising.

Igasurine crystallises in colourless prisms, having a silky lustre. It is more soluble in *water* than strychnine or brucine, dissolving in 200 parts of cold and 100 parts of boiling water; it is sparingly soluble in *ether*, very soluble in *alcohol*. The alcoholic solution turns the plane of polarisation to the left: $[\alpha] = -62{\cdot}9°$. It has not been analysed, but its atomic weight appears to be intermediate between those of strychnine and brucine.

Igasurine, when heated, melts and gives off water (about 10 per cent.); at a higher temperature, it is decomposed, with evolution of ammoniacal vapours. Strong *sulphuric acid* communicates to it a rose-colour, which passes to yellow, and then to yellowish-green. *Nitric acid* colours it deep red like brucine; on adding a few drops of stannous chloride, the colour changes to violet. *Chlorine*, passed into a very dilute solution of hydrochlorate of igasurine, produces first a rose, then a red, then a yellow colour, each bubble of gas being enveloped by a white pellicle, which is gradually deposited in the pulverulent form. If the stream of chlorine be discontinued, the precipitate redissolves on agitation, and the solution soon afterwards loses its red colour, retaining only a slight greenish tint. *Iodide of potassium*, added to a solution of igasurine, produces a crystalline precipitate after a considerable time; *ioduretted iodide of potassium* immediately forms a brown precipitate. Igasurine is not precipitated by chlorate of potassium, but its solutions yield a yellow precipitate with *tetrachloride of platinum*, white with *tannin*, and with *infusion of galls*.

Igasurine is intensely poisonous, being intermediate in power between strychnine and brucine.

Igasurine dissolves easily in dilute *acids*, and is precipitated from the solutions by *potash, soda, and ammonia*, the precipitate redissolving in excess of the alkali, especially in potash. It is also precipitated in needle-shaped crystals by *acid carbonate of sodium*, or *potassium*, in presence of tartaric acid.

The salts of igasurine are for the most part crystallisable. The *sulphate* forms colourless, silky crystals, soluble in about 4 pts. of boiling water, and 10 pts. of cold water. The *hydrochlorate* resembles the sulphate in form, but dissolves in 2 pts. of hot, and about 4 pts. of cold water. The *nitrate* forms colourless crystals, more soluble in water than either of the preceding salts.

According to Schützenberger (Compt. rend. xlvi. 1234; Ann. Ch. Pharm. cviii. 348), igasurine, prepared as above from the seeds of *Strychnos nux vomica*, yields by treatment with hot water, and fractional crystallisation, no fewer than nine distinct bases, all colourless, very bitter, and acting like strychnine. They crystallise in transparent needles, or in nacreous bulky geodes. They are reddened by nitric acid like brucine, which they also resemble in their chemical reactions, but they are more soluble in water and in alcohol. They all contain water of crystallisation (3 or 4 at.), which they give off at 100°. Schützenberger distinguishes them as *a*, *b*, *c*, &c. igasurine, and assigns to them the following formulæ:

Igasurine	*a*.	$C^{36}H^{16}N^2O^3.3H^2O$ very slightly soluble.
,,	*b*.	$C^{16}H^{24}N^2O^7.3H^2O$ slightly soluble.
,,	*c*.	$C^{16}H^{24}N^2O^4.3H^2O$ moderately soluble.
,,	*d*.	$C^{17}H^{22}N^2O^8.3H^2O$,,
,,	*e*.	$C^{16}H^{26}N^2O^4.3H^2O$,,
,,	*f*.	$C^{21}H^{30}N^2O^4.3$ or $4H^2O$,,
,,	*g*.	$C^{21}H^{28}N^2O^6.3H^2O$ very slightly soluble.
,,	*h*.	$C^{21}H^{28}N^2O^6.3H^2O$ moderately soluble.
,,	*i*.	$C^{36}H^{30}N^2O^7.3H^2O$,,

Igasurine *f* yields, by oxidation with nitrous acid, a base having the formula $C^{21}H^{28}N^2O^6$, which crystallises in colourless needles, containing 4 at. water, melting in their water of crystallisation at 100°, and coloured red by nitric acid.

In the absence of confirmatory evidences, these results must be considered rather doubtful.

IGLESIASITE. Syn. with Horn-Lead. (See Lead, Chloride of.)

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IGLITE or **IGLOÏTE.** Syn. with ARRAGONITE (i. 358).

ILDEFONSITE. A columbite from Ildefonso, in Spain, having a subme vitreo-adamantine lustre. Specific gravity 7·416 (Dana, ii. 355).

ILICIC ACID. (Moldenhauer, Ann. Ch. Pharm. cii. 350).—An acid tained in the leaves of the holly (*Ilex aquifolium*). It is known only in combin with bases. To prepare the calcium-salt, an aqueous decoction of the leaves is cipitated with basic acetate of lead; the filtrate, freed from lead by sulphydric is heated with hydrate of lead; the dissolved lead is again removed by sulph acid; and the filtrate is reduced to a syrup. The laminæ formed after some day purified by pressing, dissolving in water, precipitating with alcohol, and recrystall with the help of animal charcoal, whereby colourless ilicate of calcium is obtaine

Ilicate of calcium contains 12·86 per cent. calcium, and is readily soluble in wate insoluble in alcohol. An aqueous solution does not precipitate salts of *manganese*, *iron*, *copper*, or *silver*, but produces a precipitate with *stannous chloride*, and wit *neutral* and *basic acetates of lead*. When the lead-salts are decomposed by sulph acid, a colourless syrup is formed, which still contains lime, and by neutralisation carbonate of barium, yields amorphous ilicate of barium.

Holly-leaves gathered in January contain gum, or a similar substance, which i feres with the extraction of the acid.

ILICIN. The bitter principle of *Ilex aquifolium*. According to Délescha (Repert. Pharm. xli. 230), the decoction of the leaves is precipitated with basic ac of lead; carbonate of potassium is added to make the liquid filter, and to preci any excess of the lead-salt; and the filtrate is acidified with dilute sulphuric acid, filtered, saturated with carbonate of calcium, and evaporated to a syrup. Al extracts from the syrup a light brown, very hygroscopic substance, which, in layers, dries up to small shining scales. Or, the aqueous extract is exhausted alcohol, the alcoholic solution evaporated, and the dry residue exhausted water at 40°. The filtrate is precipitated with basic acetate of lead, freed from e of lead by sulphydric acid, evaporated, and treated with alcohol, which takes u ilicin, and leaves it behind on evaporation. The aqueous solution of the alc extract may also be treated, as above, with acetate of lead, dilute sulphuric acid carbonate of calcium in succession, the filtrate evaporated, and the ilicin extr from the residue by alcohol. It is a bitter, amorphous, brown, very hygroscopic (still containing a little potash), converted by acids at a gentle heat into a black stance, with empyreumatic odour. It is soluble in water and alcohol, insolub ether.—Lebourdin (Ann. Ch. Pharm. lxvii. 254) agitates the decoction of the l with animal charcoal, then heats it therewith to boiling; leaves it to cool; re the now colourless and tasteless liquid; washes the charcoal with cold water; it with alcohol; and leaves the filtrate to evaporate: it then leaves a colourless, bitter syrup, and finally an amorphous, neutral jelly, easily soluble in water a alcohol.—Moldenhauer's ilicin (Ann. Ch. Pharm. cii. 352) appears also to be diff from this. Moldenhauer removes the alcohol from the alcoholic extract of the l by distillation, and the separated resin by filtration; precipitates with basic acet lead; washes the yellow precipitate, and decomposes it under water with hydrosulp acid. The sulphide of lead, after being well boiled with water, yields the ilic alcohol, as a very bitter, dark brown substance, resembling tannin, and sligh water.—Bennemann (N. Br. Arch. xciii. 4) gives the name of ilicin to crystals he obtains as follows: He precipitates the decoction with basic acetate of decomposes the washed precipitate under water with sulphydric acid; filters the from the sulphide of lead, and evaporates to dryness. By repeatedly exhaustin residue with alcohol, and leaving the solution to evaporate, needles were f obtained, but not in sufficient quantity for further examination.

ILIXANTHIN. $C^{17}H^{32}O^{11}$. (Moldenhauer, Ann. Ch. Pharm. cii. 346. substance occurring in the leaves of the holly (*Ilex aquifolium*). The leaves gat in January contain scarcely any ilixanthin, while those gathered in August con large quantity. The leaves are exhausted with alcohol of 80 per cent.; the tin thus obtained is freed from the greater part of the alcohol by distillation; an residue is set aside to crystallise. The granules, which separate after some day dried, washed with ether to remove the green colouring matter of the leaves, diss in alcohol, and again separated by evaporation and addition of water; they are, recrystallised from hot water. A further quantity of ilixanthin may be obtained the mother-liquor by reducing it to a syrup, dissolving in absolute alcohol, evapo the alcoholic solution, dissolving the residue in water, and precipitating with acetate of lead. The washed precipitate is decomposed under hot water with sulph acid, and the filtrate is evaporated to a syrup, whereupon the ilixanthin crystallis in straw-yellow microscopic needles, which melt at 198° to transparent red-yellow

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Ilixanthin boils and decomposes at 215°. It does not reduce an alkaline solution of *cupric oxide*, even on prolonged boiling. It is nearly insoluble in cold *water*, but dissolves easily in hot water, forming a yellow solution; also in *alcohol*, but is insoluble in *ether*. It dissolves in warm concentrated *hydrochloric acid*. The colour of the aqueous solution is changed to orange-yellow by *alkalis* and *alkaline carbonates*, but becomes colourless on addition of sulphuric acid. *Ferrous* and *cupric salts* do not affect ilixanthin; *ferric chloride* colours it green. Neutral or basic *acetate of lead* produces in the aqueous solution of ilixanthin a splendid yellow precipitate, soluble without colour in acetic acid.

Ilixanthin forms a yellow dye on cloth prepared with alumina or iron mordants.

ILMENITE. Titaniferous Iron. See TITANATES.

ILMENIUM. According to Hermann (J. pr. Chem. xxxviii. 91, 119; xl. 475; lxv. 52), Siberian yttrotantalite, or yttroilmenite, contains a peculiar metal which forms an acid, ilmenic acid, closely resembling niobic acid (see NIOBIUM), but, nevertheless, distinguished from it by its lower specific gravity, by the insolubility of its hydrate in hydrochloric acid, and by forming with sulphuric acid a compound which is decomposed by a large quantity of water, leaving a residue of hydrated ilmenic acid. According to H. Rose, however (Pogg. Ann. lxxi. 167), the supposed ilmenic acid is merely niobic acid, more or less impure. Rose also regards yttro-ilmenite as identical with uranotantalite or Samarskite (*q. v.*)

ILVAITE. See LIEVRITE.

IMABENZILE. $C^{14}H^{11}NO$. (Laurent, Rev. scient. x. 122; J. pr. Chem. xxvii. 312.)—Produced, together with benzilam and benzilimide, by the action of ammonia on benzile:

$$C^{14}H^{10}O^2 + NH^3 = C^{14}H^{11}NO + H^2O.$$

Benzile is dissolved in warm absolute alcohol; dry ammoniacal gas is passed through the still warm solution; and the liquid is left to cool, while the passage of the gas is continued. After 24 hours, the liquid, together with the sediment which has formed, is heated to the boiling point, and filtered at the same temperature. Imabenzile then remains on the filter, and may be purified by washing with ether.

Imabenzile is a white inodorous powder, which separates from its solution in boiling ether-alcohol, in microscopic right rhombic prisms with dihedral summits, whose faces rest on the obtuse lateral edges. It melts at 140°, remains soft and glutinous on cooling, and then solidifies without crystallising. It is quite insoluble in boiling alcohol and ether. It is partially decomposed during fusion. When subjected to dry distillation, it neither gives off gas nor leaves any carbonaceous residue. When gently heated with *nitric acid*, it gives off red vapours, and yields a yellow oil, which solidifies in the crystalline form on cooling, dissolves in alcohol, and crystallises therefrom in small needles united in tufts, but is insoluble in ammonia. It is not altered by boiling with hydrochloric acid. It dissolves in gently heated *sulphuric acid*, and the solution, mixed with water, deposits benzilam. It dissolves readily in boiling alcoholic potash; and water added to the solution throws down benzilimide, while nothing but potash remains dissolved.

IMASATIC ACID. Syn. with ISAMIC ACID.

IMASATIN. $C^{16}H^{17}N^3O^3$. (Laurent, Ann. Ch. Phys. [3] iii. 483.)—A compound produced by boiling a solution of isatin in ammonia. It is of a greyish-yellow colour, often inclining to brown or green, and crystallises sometimes in lamellated grains, sometimes in radiated spheres of a darker colour. It is insoluble in water and in ether, very sparingly soluble in boiling alcohol. It is decomposed by dry distillation, yielding a large quantity of charcoal and a sublimate of colourless needles. It is not attacked by boiling hydrochloric acid. Caustic potash dissolves it, and the solution, diluted with water and neutralised by an acid, yields a whitish, gelatinous precipitate.

Dichlorimasatin, $C^{16}H^9Cl^2N^3O^3$, is a powder of slightly reddish colour, produced by the action of ammonia on an alcoholic solution of chlorisatin.

Tetrabromimasatin, $C^{16}H^7Br^4N^3O^3$. Reddish-yellow scales produced by the action of ammonia on tetrabromisatin.

IMATRA STONES. Stony concretions found in a marly formation on the Schuttgebirg in Finland. They were regarded by Parrot (Petersb. Acad. Bull. 1839, vi. 183) as petrified molluscs, on the ground that they contained calcium and sulphur, neither of which elements were found by him in the formation in which they were imbedded. On the other hand, Virlet (Bull. Géol. ii. 219; iv. 22; Jahresber. 1847-8, p. 1298) regarded them merely as calcareo-aluminous concretions produced by molecular attraction. The concretions (*A*), and the formation (*B*) in which they are found,

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have been analysed by Ulex (Jahresber. 1861, p. 1086); the latter, also (B') Salvétat (*ibid.* 1298):

	SiO^2	$CaCO^3$	Al^2O^3	Fe^2O^3	Mn^3O^4	H^2O	Alkali	TiO^2 and MgO	
A.	70·3	. .	15·1	8·8	2·1	3·7	. .	. .	= 100·0
B.	31·8	51·1	8·2	6·5	2·4	. .	. .	. .	= 100·0
B'.	34·1	47·8	9·0	4·0	2·0	. .	0·5	traces	= 97·4

IMESATIN. $C^8H^6N^2O$. (Laurent, *loc. cit.*)—Obtained by passing dry monia gas into a boiling solution of isatin in absolute alcohol, in which a slight exce pulverised isatin is suspended. It forms colourless right prisms, with rectangular l inodorous, insoluble in water, moderately soluble in boiling alcohol, very sparing ether. Heated with a small quantity of alcohol and hydrochloric acid, it diss readily and decomposes, yielding isatin and sal-ammoniac. The same decompos is produced by potash.

Chlorimesatin, $C^8H^5ClN^2O$, resembles imesatin, and is obtained in like manner chlorisatin. It forms yellow hexagonal scales, sparingly soluble in boiling alc nearly insoluble in ether. It is slowly decomposed by boiling water, with evoluti ammonia. When heated, it gives off ammonia, yields a sublimate of yellow nee and leaves charcoal.

IMIDES. Monamides, in which 2 at. hydrogen are replaced by a diatomic rad *e.g. succinimide*, $N(CO)''H$; *pyro-tartrimide*, $N(C^3H^6O)''H$. (See Amides.)

IMPERATORIA OSTRUTHIUM. (*Masterwort.*)—The root of this (analysed by Keller) contains 0·2 per cent. of a resin called imperatorin or peucedi 16·0 fat and volatile oil; 5·6 extract soluble in water and alcohol; 8·8 gum and soluble in water; 9·2 starch and extract soluble in boiling water; 41·2 vegetable and 19·0 water (and loss). (Pelouze and Frémy, *Traité*, vi. 398.)

IMPERATORIN. See Peucedanin.

INCINERATION. See Ash (i. 417).

INDELIBROMIL. $C^{16}H^8Br^4N^2O^4$.—A yellow substance, insoluble in w produced by the action of bromine on isamic acid. (Laurent.)

INDIANITE. A variety of anorthite (i. 308) found in the Carnatic, diff somewhat from ordinary anorthite (from Vesuvius) in the composition of the proto which it contains. According to Laugier's analysis (Mem. du Mus. d. hist. na 341), it contains 42·0 to 43·0 per cent. SiO^2, 34·0—34·5 Al^2O^3, 15·0—15·6 CaO, 3 2·6 Na^2O, 3·20—1·0 Fe^2O^3, and 1·0 water.

INDIAN INK or **CHINA INK.** A black pigment, the best varieties of w are imported from China. It is composed of a very fine black, said by Prechot obtained from camphor, cemented together with gelatin.

INDIAN RED. A mineral from the Persian Gulf, used as a pigment. The coarse powder has a dark red colour, with a tinge of purple. Specific gravity 3 The following analyses, A, of the entire mineral, B, of the portion soluble in h chloric acid, are by How (Edinb. New Phil. J. new series, ii. 306; Jahresber. p. 925):

	SiO^2	Fe^2O^3	Al^2O^3	CaO	MgO	SO^3	CO^2	H^2O	
A.	30·17	56·59	3·79	2·65	1·43	2·28	1·73	1·62	= 100·26
B.	(. .	3·91	2·22	2·65	0·87	2·28	1·73	. .)	= 13·66

The principal portion (insoluble in hydrochloric acid) is a ferric silicate, $Fe^2O^3.3$ The name Indian red is also applied to another pigment of similar colour, co ing chiefly of sesquioxide of iron.

INDIAN YELLOW or **PURREE.** A yellow pigment consisting essentia euxanthate of magnesium. (See Euxanthic Acid, ii. 609, and Purree.)

INDICAN. $C^{26}H^{31}NO^{17}$ (Schunck, Phil. Mag. [4] x. 73; xv. 29, 117, Jahresber. 1855, p. 660; 1858, p. 465.—Gm. xvi. 1.)—A colourless substance exi in woad, and most probably in other plants which yield indigo-blue. It likewise c in human urine, both healthy and diseased, and when present in considerable qua causes the urine, after spontaneous fermentation, or on addition of acids, to de sometimes indigo-blue, sometimes indirubin. It may be detected by precipitatin urine with basic acetate of lead, collecting the precipitate which forms in the fi on addition of ammonia, and decomposing it with cold dilute acids, the filtrate depositing, first, indigo-blue, then indirubin, and afterwards other products o decomposition of indican. Indican is also found in the blood of man, and in the and urine of the ox. (Carter, Ed. Med. J., Aug. 1859.)

Preparation.—From woad-leaves, carefully dried and pulverised while warm.—1. leaves are exhausted with cold alcohol in a percolating apparatus; the green tin

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is precipitated with alcoholic sugar-of-lead and a little ammonia-water; and the pale green precipitate, after washing with cold alcohol, is decomposed under water by a stream of carbonic anhydride; it then loses its colour, and yields a yellow solution, which, when freed from dissolved lead by sulphydric acid, and evaporated over oil of vitriol, yields indican.—2. The tincture prepared with cold alcohol is concentrated, after addition of a little water, by passing a stream of air over it at the common temperature; the fat which separates is removed by filtration; the filtrate shaken up with recently precipitated cupric hydrate; the liquid again filtered; the filtrate freed from dissolved copper by sulphydric acid; and the liquid separated from the sulphide of copper is evaporated at the temperature of the air. From the residual brown syrup, cold alcohol dissolves out the indican, leaving undissolved a brown viscid mass which contains oxindicanin. By mixing the alcoholic solution with 2 vol. ether, further products of decomposition are precipitated, whilst the indican is obtained by evaporating the filtrate. When thus prepared it still retains a little fat.

Properties.—Indican forms a yellow or yellow-brown syrup, which cannot be dried without decomposing. It has a slightly bitter and repulsive taste, dissolves in *water*, with yellow colour, also in *alcohol* and *ether*. The alcoholic solution forms, with acetate of lead, a sulphur-yellow precipitate, which increases on addition of ammonia; the aqueous solution is precipitated by acetate of lead only after addition of ammonia.

Decompositions.—1. Indican decomposes even when gently warmed, and at a stronger heat swells up and emits vapours which condense to an oil, solidifying partially in the crystalline form.

2. The aqueous solution is decomposed by heat, and by spontaneous evaporation, yielding the following products:

a. Oxindicanin, $C^{26}H^{22}NO^{16}$. This compound separates on spontaneous evaporation, and may be purified by repeated solution in water and precipitation by alcohol. It is a brown viscid combustible gum, having a nauseous taste; by boiling with dilute sulphuric acid, it is resolved into indifuscin and indiglucin:

$$\underset{\text{Oxindicanin.}}{2C^{26}H^{22}NO^{16}} = \underset{\text{Indifuscin.}}{C^{24}H^{20}N^2O^9} + \underset{\text{Indiglucin.}}{2C^6H^{10}O^5} + 4CO^2 + 3H^2O$$

b. Oxindicasin.—Produced when an aqueous solution of indican is evaporated by heat, the indican, according to Schunck, being first converted, with separation of indiglucin, into indicanin, the latter, with absorption of oxygen, into oxindicanin, and this last being resolved, with assumption of water, into oxindicasin and indiglucin:

$$\underset{\text{Oxindicanin.}}{2C^{26}H^{22}NO^{16}} + 3H^2O = \underset{\text{Oxindicasin.}}{C^{24}H^{22}N\,O^{13}} + \underset{\text{Indiglucin.}}{2C^6H^{10}O^5}$$

It is purified like the preceding, which it resembles. Its aqueous solution, precipitated with excess of neutral acetate of lead, yields a yellow lead-salt containing $C^{24}H^{22}N^2.4Pb^2O$.

c. Indicasin.—The liquid filtered from the lead-salt of oxindicasin, and containing excess of lead-acetate, yields, when treated with a large quantity of alcohol, a pale yellow precipitate = $C^{24}H^{16}N^2O^{22}.6Pb^2O$.

3. In contact with *soda-ley* or *baryta-water*, indican is resolved into indicanin and indiglucin:

$$\underset{\text{Indican.}}{C^{26}H^{31}NO^{17}} + H^2O = \underset{\text{Indicanin.}}{C^{26}H^{29}NO^{16}} + \underset{\text{Indiglucin.}}{C^6H^{10}O^5}$$

A solution of indican, left for several days in contact with soda-ley, yields, with acids, indirubin produced from the indicanin; after longer standing, indiretin is likewise obtained, and in some cases the latter is the only product.

4. Indican is decomposed by dilute *acids* in the cold, and more quickly when heated. The decomposition is induced by tartaric and oxalic acids, as well as by mineral acids, less easily by acetic acid. Aqueous indican mixed with dilute sulphuric acid, becomes turbid on standing, and deposits blue flocks, the formation of which ceases after 24 hours. The filtrate, after standing for some time, and still more when heated, deposits a brown powder, while leucine and indiglucin remain in solution, together with certain volatile products, viz. carbonic, formic, acetic, and perhaps propionic acid, which escape when the liquid is heated.

The substance insoluble in water is a mixture of six different bodies. On exhausting it, first with cold, then with warm dilute soda-ley, *indikumin*, *indifuscin*, and *indiretin* are dissolved; the residue yields to alcohol, *α-* or *β-indifulvin* and *indirubin*, together with residues of indifuscin, while *indigo-blue* remains in solution. Instead of indifuscin, *indifuscone* is sometimes obtained. Schunck gives the following formulæ:—

a. Formation of indigo-blue or its isomer, indirubin, and of indiglucin:

$$\underset{\text{Indican.}}{C^{26}H^{31}NO^{17}} + 2H^2O = \underset{\text{Indigo-blue.}}{C^8H^5NO} + \underset{\text{Indiglucin.}}{3C^6H^{10}O^5}$$

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Part of the indigo-blue is said to split up into leucine, formic acid, and carb anhydride:

$$\underset{\text{Indigo-blue.}}{C^{8}H^{5}NO} + 5H^{2}O = \underset{\text{Leucine.}}{C^{6}H^{13}NO^{2}} + \underset{\text{Formic acid.}}{CH^{2}O^{2}} + CO^{2}$$

b. Formation of *α*-indifulvin, indiglucin, and formic acid:

$$2C^{26}H^{31}NO^{17} + 5H^{2}O = \underset{\alpha\text{ Indifulvin.}}{C^{22}H^{20}N^{2}O^{3}} + \underset{\text{Indiglucin.}}{4C^{6}H^{10}O^{6}} + \underset{\text{Formic acid.}}{6CH^{2}O^{2}}$$

c. Formation of *β*-indifulvin, indiglucin, formic acid, and carbonic acid:

$$\underset{\text{Indican.}}{4C^{26}H^{31}NO^{17}} + 7H^{2}O = \underset{\beta\text{ Indifulvin.}}{C^{44}H^{38}N^{4}O^{3}} + \underset{\text{Indiglucin.}}{8C^{6}H^{10}O^{6}} + \underset{\text{Formic acid.}}{10CH^{2}O^{2}} + 2CO$$

d. Formation of indihumin, indiglucin, propionic acid, and carbonic anhydride

$$\underset{\text{Indican.}}{C^{26}H^{31}NO^{17}} + 2H^{2}O = \underset{\text{Indihumin.}}{C^{16}H^{9}NO^{3}} + \underset{\text{Indiglucin.}}{2C^{6}H^{10}O^{6}} + \underset{\text{Propionic acid.}}{C^{3}H^{6}O^{2}} + CO^{2}$$

e. Formation of indifuscone, indiglucin, acetic acid, and carbonic anhydride

$$\underset{\text{Indican.}}{2C^{26}H^{31}NO^{17}} + 3H^{2}O = \underset{\text{Indifuscone.}}{C^{32}H^{20}N^{2}O^{5}} + \underset{\text{Indiglucin.}}{4C^{6}H^{10}O^{6}} + \underset{\text{Acetic acid.}}{2C^{2}H^{4}O^{2}} + 2CO$$

f. Formation of indiretin, indiglucin, carbonic anhydride, and water:

$$\underset{\text{Indican.}}{C^{26}H^{31}NO^{17}} = \underset{\text{Indiretin.}}{C^{16}H^{17}NO^{5}} + \underset{\text{Indiglucin.}}{C^{6}H^{10}O^{6}} + 2CO^{2} + 2H^{2}O$$

INDICANIN. $C^{20}H^{23}NO^{12}$. (Schunck, Phil. Mag. [4] xv. 183.)—This pound is produced, together with indiglucin, by the action of aqueous alkalis or ba water on indican:

$$C^{26}H^{31}NO^{17} + H^{2}O = C^{20}H^{23}NO^{12} + C^{6}H^{10}O^{6}.$$

Indicanin is left in contact with baryta-water; the liquid is precipitated with d sulphuric acid; and the filtrate is freed from excess of sulphuric acid by carbon lead, from lead by sulphydric acid, and evaporated in a stream of air at mean tem ture. The residue is dissolved in alcohol; the solution is mixed with twice its vo of ether, which precipitates indiglucin; and the filtrate is left to evaporate.

Indicanin is a yellow or brown bitter syrup, soluble in *water*, *alcohol*, and When heated on platinum-foil, it swells up strongly and leaves charcoal. By dry tillation it yields a brown oil in which white needles form. When boiled with it yields indiglucin and indirubin, and if impure, likewise indiretin and indifu Formation of indirubin:

$$C^{20}H^{23}NO^{12} + H^{2}O = C^{8}H^{5}NO + 2C^{6}H^{10}O^{6}.$$

When boiled with *soda-ley*, it gives off ammonia.

Aqueous indicanin forms a slight precipitate with neutral acetate of *lead*; alcoholic indicanin an alcoholic solution of neutral acetate of lead throws down a co sulphur-yellow precipitate, soluble in excess of the lead-acetate, precipitable by monia, and containing $C^{20}H^{23}NO^{12}.3Pb^{2}O$.

INDIFULVIN. (Schunck, *loc. cit.*)—This name is applied to two compou distinguished as *α* indifulvin, $C^{22}H^{20}N^{2}O^{3}$, and *β* indifulvin, $C^{44}H^{38}N^{4}O^{3}$, which obtained, together with indifuscin, indiglucin, indigo-blue, indihumin, indiretin, indirubin, by treating indican with dilute acids.

Preparation.—Indican is heated with dilute sulphuric acid; the flocks which rate are collected (the solution which runs off being preserved for the preparati indiglucin), washed with cold water, and treated, first with cold, then with warm d soda-ley, which dissolves one portion, and leaves another containing *α*- and *β*-indifu indirubin, and indigo-blue. The alkaline solution is precipitated with hydroch acid, and the precipitate is collected, washed, and treated with boiling ammonia, w dissolves indifuscin and indiretin, and leaves indihumin. The ammoniacal solu neutralised with acetic acid, yields a precipitate of indifuscin, and an additi quantity of this product is precipitated from the filtrate by alcoholic sugar-of-lead. indiretin which still remains in solution is separated by ammonia, in combination lead-oxide and contaminated with indifuscin; it is separated from the lead-oxid treating the precipitate with acetic and then with hot hydrochloric acid, and pur by repeated solution in alcohol, which leaves the indifuscin undissolved.

The mixture of *α*- and *β*-indifulvin, indirubin, and indigo-blue, insoluble in d soda-ley, gives up to boiling alcohol everything excepting the indigo-blue. The pu brown alcoholic solution, mixed with ammonia and alcoholic sugar-of-lead, dep residues of substances soluble in soda-ley; and on separating these, then adding ex of acetic acid, distilling off the alcohol, and diluting largely with water, purple-b flocks are obtained, from which, when purified with dilute soda-ley, a small quanti cold alcohol extracts indifulvin. On boiling the residue with an alkaline solutio protochloride of tin, filtering hot, and exposing the filtrate to the air, a purpl

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deposit is formed, consisting of indirubin. This is washed with water and dissolved in alcohol. The portion insoluble in the alkaline solution is a mixture of indirubin and indifulvin.

Indifulvin is obtained of various composition, *α* or *β*, according to circumstances not well understood. It is a brittle, friable, reddish-yellow resin, which, when heated, melts, burns with flame, and leaves charcoal. Heated in a glass tube, it gives off a strong-smelling vapour, condensing to a brown oil, which solidifies in the crystalline form. Dissolves in strong *sulphuric acid*, with green-brown colour, and chars when heated. By ordinary *nitric acid*, it is scarcely attacked, even at the boiling heat; but it dissolves in fuming nitric acid, and is precipitated by water in orange-yellow flocks. By heating and evaporating the liquid, a yellow resin is obtained, together with crystals soluble in water, and different from oxalic acid. It is slowly decomposed by *chromic acid*. It does not dissolve in aqueous *alkalis*, even at the boiling heat, or on addition of grape-sugar, or dichloride of tin.

INDIFUSCIN, $C^{34}H^{20}N^2O^8$, and **INDIFUSCONE**, $C^{32}H^{20}N^2O^8$?—These compounds are produced in greatest quantity by the action of dilute sulphuric acid on indican which has been previously exposed to the air. A brown powder is then formed, containing from 59·4 to 67·5 per cent. C, 5·78 to 7·12 N, and 29·12 to 20·23 O, so that it appears to agree, sometimes with one, sometimes with the other of the formulæ just given. When heated, it emits vapours, with an odour of burning turf, and yields an oily distillate. It burns without fusion; colours *chromic acid* green; with boiling *nitric acid*, it yields oxalic and picric acids; dissolves in strong sulphuric acid, with brown colour, giving off sulphurous anhydride when heated. It is insoluble in boiling water; dissolves easily in alcoholic *ammonia*, whence it is precipitated in brown flocks by acids; also in aqueous *alkalis* and *alkaline carbonates*, and is precipitated therefrom by *metallic salts*; sparingly soluble in boiling *alcohol*.

INDIGLUCIN. $C^6H^{16}O^6$. (Schunck, Phil. Mag. [4] x. 73; xv. 183; Jahresber. 1856, 659; 1858, 465; Gm. xv. 302.)—Produced, together with the products above mentioned, by heating indican, indicanin, oxindicanin, or oxindicasin, with water, acids, or alkalis (pp. 247, 248).

Preparation.—Tincture of woad-leaves, prepared with cold alcohol, is evaporated in a current of air; the residue is mixed with cold, very dilute sulphuric acid, and the fat which falls to the bottom is immediately separated by filtration. The filtrate serves instead of the acidulated aqueous solution of indican. The decomposition, which begins in the cold, is kept up by gentle heating, whereupon the solution becomes turbid, and a mixture of six insoluble substances separates (p. 247); the liquid is then filtered, the residue washed with cold water, and decomposed in the manner described under indican. The filtrate, freed from sulphuric acid by carbonate of lead, and from lead by sulphuric acid, evaporated to a syrup in a stream of air, dissolved in alcohol, and mixed with a large quantity of ether, deposits leucine in crystals, and indiglucin as a syrup. The latter, after the removal of the crystals, is dissolved in water; the solution is mixed with acetate of lead; the scanty precipitate is removed; and the yellow lead-compound of indiglucin is precipitated from the filtrate by aqueous ammonia. The lead-salt decomposed by sulphydric acid under water, and treated with animal charcoal till a sample gives a white precipitate with ammoniacal sugar-of-lead, yields a solution from which, by evaporation, solution of the residue in alcohol, and addition of ether, the indiglucin is precipitated in the form of a syrup.—2. In the preparation of indicanin from indican, by mixing the latter with baryta-water and leaving it at rest, then removing the baryta, evaporating the filtrate in a current of air, dissolving the residue in alcohol, and precipitating by ether, indiglucin is separated as a syrup. This syrup is dissolved in alcohol, mixed with excess of alcoholic sugar-of-lead, the brown precipitate removed, and the solution precipitated with ammonia. The lead-compound of indiglucin is purified and decomposed as in method 1.

Indiglucin is a colourless or light yellow syrup having a slightly sweet taste, soluble in *water* and in *alcohol*, but precipitated from the alcoholic solution by *ether*.

It swells up when heated, and gives off an odour of caramel. With boiling *nitric acid*, it forms oxalic acid. With strong *sulphuric acid*, it becomes carbonised. When boiled with *soda-ley*, it turns yellow, and separates brown flocks. From an *alkaline cupric solution* it reduces cuprous oxide; from an aqueous and still more from an *ammoniacal* solution of *nitrate of silver*, it reduces metallic silver; similarly with *trichloride of gold*. It is not fermentable, but turns acid by prolonged contact with *yeast*.

Aqueous indiglucin dissolves *hydrate of calcium*, and the solution on boiling deposits copious yellow flakes, which dissolve on cooling, and are precipitated by alcohol. From a mixture of indiglucin with *baryta-water* alcohol throws down yellow flakes.—Aqueous indiglucin is precipitated by neutral or basic acetate of *lead*, only after addition of ammonia; the precipitate has the composition $C^{12}H^{18}Pb''O^{12}.3Pb''O$.

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INDIGO-BLUE. C^8H^5NO or $C^{16}H^{10}NO^2$.—*Blue Indigo. Indigotin. Oxidized Indigo* (Gm. xiii. 35; Gerh. iii. 514).—This important colouring matter was known in India and in Egypt before the Christian era, and is mentioned by Dioscorides and Pliny under the names *ἰνδικόν* and *indicum*. Egyptian mummies have been found wrapped in blue cloths, the colour of which exhibited all the characters of indigo. The Romans used it only as a pigment, not being acquainted with the method of dissolving it. Its introduction into Europe as a dye is generally attributed to the Jews, who during the middle ages practised the art of dying with indigo in the Levant. It was first imported in large quantities into the European markets from India in the seventeenth century by the Dutch.

Indigo is chiefly obtained from various species of *Indigofera*, namely, *I. tinctoria*, *I. Anil*, *I. disperma* and *I. pseudotinctoria*, cultivated especially in the East and West Indies; also from *Nerium tinctorium* and *Calanthe veratrifolia*, natives of Hindostan; *Asclepias tinctoria* and *Marsdenia tinctoria* of Sumatra, *Polygonum tinctorium*, *Isatis indigotica*, *Justicia tinctoria* and *Bletia Tankervillia* of China, and *Amorpha fruticosa* of Carolina. The only European plant which yields true indigo-blue is woad (*Isatis tinctoria*), which was extensively used for blue-dyeing before the introduction of indigo; but it is much less rich in indigo than the tropical plants above mentioned, and is now used only as an addition to the indigo-vat (p. 252). The following European plants also yield blue colouring matters more or less resembling indigo, but apparently not identical with it: *Astragalus glycyphyllus*, *Centaurea Cyanus*, *Chelidonium majus*, *Cicer arietinum*, *Colutea arborescens*, *Coronilla Emerus*, *Galega officinalis*, *Hedysarum Onobrychis*, *Inula Helenium*, *Iris germanica*, *Lotus corniculatus*, *Medicago sativa*, *Mercurialis perennis*, *Polygonum aviculare*, *Polygonum Fagopyrum*, *Rhinanthus Crista-galli*, *Sambucus nigra*, *Sambucus Ebulus*, *Scabiosa succisa* and *Vaccinium Myrtillus*.

Indigo-blue is sometimes deposited from human urine both healthy and diseased, being produced by spontaneous fermentation from indican (p. 246). It has also been occasionally observed to form in the milk of cows, especially such as have been fed exclusively on sainfoin.

With regard to the state in which indigo exists in the plants from which it is obtained, and the nature of the process by which it is converted into indigo-blue, various opinions have been entertained. Roxburgh (*Transactions of the Society of Arts*, vol. xxviii.) supposed that indigo plants contain only the base of the colouring matter, which of itself is green; that it is kept in solution by the carbonic acid evolved in the preparation of indigo, set free by the addition of alkalis, and absorbs from the air a substance which converts it into indigo-blue. Giobert (*Traité sur le pastel*, Paris 1813) supposed that indigo-plants contain colourless indigogen, which is soluble in water and contains more carbon than indigo-blue, into which it is converted, with formation of carbonic acid, by absorbing oxygen from the air. This oxidation is promoted by heat or by the presence of alkalis, especially by lime; it is arrested by acids, even by carbonic acid. (Giobert.)

According to Chevreul (Ann. Chim. lxvi. 8; lxviii. 284), woad and other indigo-plants contain indigo-white, C^8H^6NO, which contains 1 at. H more than indigo-blue, and being held in solution by the sap, is converted into indigo-blue by oxidation, on exposure to the air:

$$2C^8H^6NO + O = 2C^8H^5NO + H^2O.$$

This explanation, being the simplest, was very generally adopted, until Schunck (Phil. Mag. [4] xv. 29) pointed out that white indigo cannot exist in any plant, since it requires free alkali for its solution, whereas the sap of plants is always acid, and moreover contains free oxygen. Schunck has further shown that woad contains indican, (p. 246), which is readily soluble in water, and when boiled with acids splits up into indigo-blue and indiglucin, without the intervention of oxygen:

$$\underset{\text{Indican.}}{C^{26}H^{31}NO^{17}} + 2H^2O = \underset{\text{Indigo-blue.}}{C^8H^5NO} + 3\underset{\text{Indiglucin.}}{C^6H^{10}O^5}.$$

The same substance probably exists in other indigoferæ, and in other plants from which indigo is obtained, and during the steeping process, presently to be described, is resolved, in consequence of the fermentation which takes place, into indigo-blue and indiglucin.

Preparation of Commercial Indigo.—1. *From fresh leaves.*—In Bengal, the plants, which are cut close to the ground whilst the blossom is unfolding, are placed in a brick cistern (*steeping vat, Gährungsküpe, trempoire, pourriture*), which is filled several inches deep with cold water, and allowed to ferment. At 30° C. (86 F.) the fermentation is finished in from 12 to 15 hours; at lower temperatures it requires a longer time. The gas evolved is a mixture of carbonic anhydride and atmospheric air from which the

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oxygen has been absorbed. When the liquid no longer rises, it is drawn off into the *beating vat* (*Schlagekūpe, batterie*) which stands lower, where it is kept stirring for an hour and a half or two hours, whereupon carbonic anhydride is evolved and the indigo at first separates in large flakes. When, after being repeatedly stirred, it forms grains like fine sand, and the solution is clear, the indigo is allowed to settle. After two or three hours, the liquid is drawn off from the deposit. If the fermentation is properly conducted, the indigo settles readily down, the liquid is of a malaga-brown colour, and forms a thick foam which rapidly disappears. The deposit is boiled for three or four hours in a copper vessel and then thrown upon a linen filter; it is afterwards pressed, cut into squares, and dried by heat. 1000 pts. of the solution of the leaves yield from 0·5 to 0·7 pts. of indigo; more is precipitated on the addition of potash-ley or lime-water, but it is not so pure.

Respecting the manufacture of indigo in the Caucasus, see *Dingl. pol. J.* 126, 304.

2. *From dry leaves.*—In the southern parts of India, the leaves of the indigo plant are dried, and packed up for a month, more or less, at the expiration of which time they assume a light lead colour; by additional keeping the lead-colour gradually darkens till it becomes black. Experience has proved that the leaves will not give out any colouring matter to cold water till the first change has commenced, when the maximum quantity of indigo seems to be developed; and that from this period it diminishes. If from fear of rain the plant be cut too soon, the leaves should be kept proportionally longer; but if, from want of sufficient sunshine, the cutting be deferred till after the plant is fully ripe, the leaves will not require to be kept so long.

These leaves, after due keeping, are transferred to the steeping-vat, where they are infused in water, in the proportion of about one volume of leaves to six of water, and allowed to digest for two hours, with occasional stirring. The water is then run off through strainers into the beating-vat, where it is agitated by the paddles of ten or twelve natives for about two hours, during which time the fine green liquor gradually darkens to a blackish hue. Lime-water is now thrown into the vat, and well mixed with the liquor. The supernatant Madeira-coloured liquid is run off after repose, and the subsided blue indigo is drained on cloth. Next morning it is mixed with water in a copper and boiled; after which the whole is thrown on strainers, and the indigo collected is dried and formed into cakes. (Weston, *Journal of Scienos*, xxvii. 296.)

Indigo is obtained in the same way in the south of France from a hot extract of *Nerium tinctorium* and *Polygonum tinctorium* (J. Pharm. xxvi. 276; J. pr. Chem. xvi. 180). Indigo was formerly prepared from woad in a similar manner, by employing tepid water and precipitating with lime-water; a deeper colour was imparted to the product by extracting the carbonate of calcium with hydrochloric acid. The preparation of indigo from *Polygonum tinctorium* is rendered difficult by a resin which the plant contains. This resin is separated by mixing the bruised leaves with one-tenth of their weight of protosulphate of iron, and adding a sufficient quantity of water, together with an excess of carbonate of potassium; the whole is then thrown upon a filter, and the solution mixed with sufficient nitric acid to render it slightly acid. On neutralising with carbonate of potassium, it becomes blue and deposits all the indigo-blue within 24 hours; the indigo has then the same properties as that obtained from *Indigofera*. (Gaudry, N. J. Pharm. v. 133.)

Purification.—Commercial indigo contains from 50 to 60 per cent. of pure indigo-blue, the remainder consisting of indigo-gluten, indigo-red, indigo-brown, and a number of brown resinous products, &c., formed either by decomposition of the indigo-blue produced in the first instance, or directly from the indican itself (p. 246). Certain substances are also occasionally added to indigo for the purpose of adulteration.

Indigo may be purified from most of these foreign matters by treating it successively with dilute sulphuric or hydrochloric acid, with boiling water, and with alcohol. This treatment however does not yield a chemically pure product, and it is better to resort to the process of the vat, which consists in converting the indigo-blue into indigo-white by the action of reducing agents, and subsequently reoxidising it. This process is also one of great industrial importance, being that which is used by dyers for rendering indigo soluble and fixing it upon tissues.

a. Cold Vats.—1. *Copperas* or *common blue vat.* (*Cuve à la couperose, Vitriol-kūpe.*) In this, which is the kind of cold vat generally used for dyeing cotton, hemp, and flax, the indigo-blue is reduced by the action of protosulphate of iron. 1 pt. of finely ground indigo is mixed with hot water, in which 4 pts. of quick-lime are slaked; to this is added a solution of 3 pts. of sulphate of iron free from copper, the whole being stirred. (If the sulphate of iron is yellowish, one-third more is taken.) Water is added, to the amount of 100 or 200 times the weight of the sulphate of iron, according as the dye is required dark or light, and the whole, after being stirred, is left at rest. The proportions quoted are those most commonly used in dyeing; when the indigo is particularly pure, more lime and sulphate of iron must be taken. An excess of lime

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yields a *sharp* vat (*scharfe Küpe*), from which the threads of the material readily take up the dye; too little lime yields a *soft* vat (*leise Küpe*), which dye so well. On the addition of carbonate of potassium, a compound of indi with potash is formed. A sediment is formed and a yellow solution, which covered with a copper-coloured film (flower); the solution is drawn off f sediment, and deposits tolerably pure indigo-blue on exposure to the air.—Th digests commercial indigo with lime, sulphate of iron, and water, and expose air the decanted solution of the compound of indigo-white with lime; he then the carbonate of calcium from the blue precipitate with hydrochloric acid, indigo-red with water, afterwards washes with water and dries.—Berzelius mix of indigo (purified according to 1) with 6 pts. of quick-lime freshly slaked, 4 sulphate of iron, and 450 pts. of boiling water; he then closes the vessel and repeatedly; allows the whole to subside, and removes the yellow solution by me siphon; again adds hot water, and draws it off after repeated shaking; and m whole of the solution with hydrochloric acid; this is exposed to the air and sh the indigo is completely oxidised; it is then thrown on a filter and washed wit —Erdmann mixes together 1 pt. indigo, 2 pts. sulphate of iron, 3 pts. li 60 pts. water; draws off the clear solution; mixes it, stirring repeatedly, wit hydrochloric acid; and washes the precipitate in contact with the air. The residu fresh quantities of indigo-blue when again stirred up with hot water, and with necessary. The indigo-blue thus obtained contains a little gypsum, at most cent., and indigo-red, which it is difficult to remove by boiling with alcohol; it to reduce the indigo again in the cold vat and precipitate it with hydrochloric According to Dumas, a little sulphide of calcium is formed in the vat, and hence is mixed with the indigo when it is precipitated by hydrochloric acid; this he with sulphide of carbon.

2. In the so-called *orpiment-vat*, a solution of the compound of indigo-wh potash is formed in a mixture of indigo-blue with trisulphide of arsenic, pot water, by the oxidation of the resulting sulpharsenite of potassium; the deposits indigo-blue when exposed to the air. This kind of vat is chiefly calico-printing, not for dyeing properly so-called.

3. In the *tin-vat*, commonly used for calico-printing, the indigo is reduc solution of stannous oxide in caustic potash or soda. The bath is usually mi an acid solution of tin, so as to neutralise the alkali and precipitate the indig the precipitate is then used for printing.

b. Warm vats.—1. *Woad-vat.* (*Pastel-vat.*) On mixing from 2 to 6 finely powdered indigo with from 30 to 50 pts. woad, 2 pts. madder, 2 pts. b 8 pts. potash, and ½ pt. lime, and warming with 1000 pts. water (6000 to 700 at 80° C. (176° F.), a fermentation is set up in which water is decomposed nascent hydrogen forms indigo-white, which combines with the ammonia taneously formed. The brownish-yellow liquid first becomes green on exposu air, and then deposits indigo-blue; it may be used for dyeing for three to six mon vided it be kept warm, and madder, bran, indigo or potash added from time to required. Beetroot-molasses and malt may be advantageously used instead of

The use of madder, bran, &c. in this process appears to depend upon the gu amylaceous substances and the pectic acid which they contain. These substa probably transformed, first into lactic, then into butyric acid, in which transfo hydrogen is evolved, which reduces the indigo-blue to indigo-white. The woa same time undergoes putrefaction, and gives off ammonia, which keeps the white in solution. The lime seems to act chiefly by neutralising the excess produced by the decomposition of the amylaceous and gummy matters.

2. In the *potash* or *Indian vat*, in which woad and lime are not used, 3 pts. c are added to a mixture of 2 pts. madder, 2 pts. wheat-bran, 6 pts. potas 1000 pts. water at 60° C. (140° F.); after 36 hours, 3 pts. potashes, and after more the same quantity of potashes, are likewise added. This vat is easier to than the woad vat.

3. The *urine-vat* is employed only in small dye-houses and in certain loca at Verviers, for the dyeing of wool. The putrefying urine furnishes at once the agents to convert the blue into white indigo, and the ammonia necessary to the latter. [For further details respecting the manufacture of indigo and it dyeing, see *Ure's Dictionary of Arts, &c.* ii. 498.]

To obtain indigo-blue in the crystalline state, 4 oz. of raw indigo and 4 oz. sugar are introduced into a flask capable of containing 12 lbs. water, to which the strongest soda-ley are added. The whole is well shaken, and the flask co filled with hot alcohol; it is then tightly corked and allowed to stand for sever until the solution is sufficiently clear to permit its being siphoned off into flask. The flask is allowed to stand loosely covered; the solution, at first of a

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yellowish-red colour, now gradually turns blue, whilst indigo separates out. The solution is filtered and the indigo is washed, first with alcohol and then with water, till the filtrate is colourless. In this manner, 2 oz. (50 per cent.) of pure indigo-blue is obtained. If the brown alcoholic solution is poured back hot into the first flask, it yields 3 per cent. more indigo; but it is then nearly exhausted (Fritzsche, Marchand).—Indigo also forms a vat immediately with grape-sugar, caustic soda, and hot water; the decanted solution, when exposed to the air, deposits indigo-blue containing a quantity of indigo-red, which may be extracted by an alcoholic solution of soda. (Fritzsche.)

Purification of indigo by sublimation.—When powdered commercial indigo is heated on a watch-glass, a silver dish, or a spoon, a network of crystals is formed, which may be removed with a pair of forceps, and the crystals carefully separated from adhering particles of carbon, under a magnifying glass (Le Royer and Dumas; Dumas).—Crum heats indigo between two platinum crucible lids, which are separated from one another by a distance not greater than $\frac{3}{4}$ inch, till the hissing sound ceases.—Berzelius sublimes indigo in an exhausted retort, of the size of a chicken's egg, cuts off the upper part of the retort when the crystals have sublimed, and separates the lower crystals from the adhering particles of carbon. The crystals are freed by ether from traces of oil and resin.—Taylor stirs up an intimate mixture of 2 pts. finely powdered indigo and 1 pt. gypsum with water into a thin paste, which he spreads upon sheet iron in layers 2 inches broad and $\frac{1}{8}$ inch deep. These are dried by exposure to the air, then heated at one end with a spirit-lamp till red vapours are evolved, and so the operation is continued. If the mass catches fire, it is extinguished by a drop or two of water. The velvety indigo can easily be separated, and may be purified by alcohol and ether. (Med. Gaz. 1843, 130.)

Preparation of Indigo-blue from Indican.—The aqueous solution of indican from woad-leaves, which must not be too dilute, is boiled with sulphuric acid or hydrochloric acid; and the abundant purple-blue precipitate is filtered off and washed, first with water and then with boiling alcohol, till the filtrate is of a pure blue colour: the residue consists of pure indigo-blue. Nitric, oxalic, tartaric, and acetic acids are also capable of converting indican into indigo-blue: acetic acid, however, acts less powerfully than the rest. (Schunck.)

Properties.—Indigo-blue sublimes in right rhombic prisms (Miller); in six-sided prisms derived from a rhombic prism of 32° and 148°, and having their bases replaced by two faces which seem to form an obtuse angle with one another (Laurent). Its lustre is semi-metallic, and by reflected light, dark-red inclining to copper-red (according to Crum, it is red when viewed obliquely under the microscope; and of a brilliant blue when viewed perpendicularly). When prepared in the wet way, it is dark blue, and acquires by pressure a dark copper colour and almost metallic lustre. It is inodorous and tasteless, and does not react upon vegetable colours.—In open vessels, it volatilises at about 288° in dark purple-red vapours; in closed vessels, it decomposes partially when heated (Crum). It volatilises without decomposition only in a current of air or in vacuo; the powder dropped on a piece of heated platinum foil, volatilises in purple vapours without leaving a residue, each particle being supported by the vapour without coming in contact with the foil (Dumas). It is quite insoluble in *water*, dilute *acids*, and *alkalis*, *ether*, and *volatile oils*; also in *alcohol* and *fixed oils* at common temperatures; but hot alcohol, and fixed oils heated above 100°, dissolve small quantities, and deposit it again on cooling. Sublimed indigo dissolves pretty readily in hot *phenic acid*, forming a blue liquid when mixed with a little alcohol, but precipitated by a larger quantity. Sublimed indigo also dissolves to a small extent in hot *oil of turpentine*.

Indigo-blue is isomeric with cyanide of benzoyl.

Decompositions.—1. Indigo-blue melts and boils when heated in contact with the *air*; at higher temperatures it burns with a bright and very smoky flame, leaving a residue of difficultly combustible charcoal (Berzelius). By exposure to air containing *ozone* it is quickly converted into isatin. (Erdmann, J. pr. Chem. lxxi. 209.)

2. By dry distillation, it yields a very little undecomposed sublimate, together with carbonate and cyanide of ammonium, phenylamime, empyreumatic oil, and a large residue of shining charcoal (Crum). On heating indigo-blue in vacuo, a brown oil is formed, together with a large proportion of sublimed indigo, but no permament gas or aqueous liquid; by rapid heating, more sublimate is obtained, and a fused shining charcoal; on heating more gradually, less sublimate is formed, together with a dull earthy charcoal. (Berzelius.)

3. Dry *chlorine* does not act upon indigo-blue between 0° and 100°. If indigo-blue is stirred up with water into a thin paste, and chlorine passed through while the whole is kept cool, the mass becomes first greyish-green and then yellow. Neither carbonic anhydride nor any other gas is evolved. An orange-coloured deposit is

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formed, and a yellowish-red solution; on distilling, trichlorophenic acid and trichlorophenylamine sublime, and a liquid distils over which smells of anisic acid, and contains hydrochloric and trichlorophenic acids. The residue in the retort dissolves in boiling water, leaving a brown resin, which is formed in small quantity only. If the mass is cooled as much as possible during the action of the chlorine, and the passage of the chlorine is interrupted before all the indigo-blue is destroyed, the boiling aqueous solution deposits, on cooling, a yellowish-red crystalline powder, which yields chlorisatin and dichlorisatin when recrystallised from alcohol. (Erdmann.)

4. *Bromine* acts upon indigo in the same manner as chlorine. On treating moist indigo with bromine, a yellow mass is formed, which yields, by distillation, tribromophenic acid and tribromophenylamine; the residue contains a little bromisatin, a large proportion of dibromisatin, and a little resinous matter. (Erdmann.)

5. *Iodine* decomposes indigo only when heated. (Berzelius.)

6. Indigo is decomposed by heating it with *chlorate of potassium* and *hydrochloric acid*. Only traces of chloranil are formed. (Hofmann.)

7. When boiled with dilute *nitric acid*, it gives off a large quantity of gas, and forms isatin and a brown resin; with a stronger acid, it forms principally nitrosalicylic acid, and with an excess of nitric acid of specific gravity 1·43, it yields picric acid; at the same time carbonic anhydride, prussic acid, oxalic acid, and the so-called artificial indigo-resin are formed. 5 pts. of fuming nitric acid becomes so violently heated with 1 pt. powdered commercial indigo that the mass takes fire.

8. Concentrated *chromic acid* destroys indigo-blue immediately, especially when heat is applied, with violent evolution of carbonic anhydride and precipitation of sesquioxide of chromium. Dilute chromic acid forms a clear yellow-brown solution with indigo; if this is heated to near the boiling point and filtered, isatin crystallises out on cooling (Erdmann). Chlorochromic acid does not act upon indigo-blue. (Thomson.)

9. On boiling indigo-blue with *peroxide of lead*, a pale yellow solution is formed, which becomes turbid on cooling, and leaves a yellow powder when evaporated to dryness. This substance being suspended in water and decomposed with sulphydric acid, yields a brownish-yellow filtrate, which on evaporation leaves a residue consisting of a small quantity of brown resin and a few crystals. The sulphide of lead contains a brown resin, melting at 100°, which may be extracted by boiling alcohol, and precipitated by water; boiling water extracts from it a substance which, on evaporation, deposits crystals mixed with resin. (Erdmann.)

10. *Manganic sulphate*, *manganate of potassium*, and *permanganate of potassium* decolorise indigo (Lefort, Rev. scient. 16, 358). On heating indigo-blue for a considerable time with aqueous *osmic acid*, oxalic acid is formed. (Buttlerow, J. pr. Chem. lvi. 278.)

11. When the vapour of *sulphuric anhydride* is passed over roughly pulverised commercial indigo, the latter swells up, becomes heated, and a beautiful purple-red liquid is formed, which is transparent in thin layers, and solidifies into a crimson mass. In contact with the air, it evolves sulphurous anhydride (probably on account of the impurities of the indigo), and dissolves in common sulphuric acid with a violet colour; on dissolving it in water, charcoal separates out and a dark blue solution is formed (Döbereiner; Bucholtz; Bussy). Indigo dissolves, with evolution of heat, in excess of fuming or of common *sulphuric acid* (no gas is evolved if the indigo is pure) with formation of sulphindigotic acid; if an excess of sulphuric acid is not added, more or less sulphophœnicic acid is formed. According to Berzelius, hyposulphindigotic acid is also formed when indigo is dissolved in fuming sulphuric acid. Indigo-blue dissolves in cold sulphuric acid, first with a yellow colour, which afterwards becomes green, and finally of a beautiful blue (Housmann, Journ. de Phys. 1788; March, Chevreul). From the solution, while still yellow, undecomposed indigo-blue may be precipated by water; the yellow colour changes to blue in a few hours in a closed vessel, since sulphophœnicic acid is formed, which is gradually converted into sulphindigotic acid. When indigo is more strongly heated with sulphuric acid, sulphurous anhydride is evolved, and a brown oily liquid formed (Döbereiner). Liquid sulphurous anhydride does not act upon indigo (Bussy). Phosphoric anhydride and hydrated phosphoric acid are without action upon indigo; also concentrated hydrochloric acid. (Döbereiner.)

12. Indigo-blue is but slightly attacked by prolonged boiling with dilute *potash*; when the boiling point has reached 100°, the indigo is completely decomposed, whilst no gas is given off, and only traces of ammonia and phenylamine are evolved with the aqueous vapour (Fritzsche). According to Gerhardt (Rev. scient. x. 371), indigo-white and isatate of potassium are formed in this reaction:

$$\underset{\text{Indigo-blue.}}{3C^8H^5NO} + KHO + H^2O = \underset{\text{Indigo-white.}}{C^{16}H^{12}N^2O^2} + \underset{\text{Isatate of potassium.}}{C^8H^6KNO^3}$$

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According to Fritzsche, a yellowish-red solution is first formed, on which a dark coloured substance floats, and from which yellow crystals of chrysanilate potassium are separated by continued boiling; on cooling, it solidifies into a crystalline mass, consisting principally of chrysanilate of potassium. The crystalline mass, when water is poured over it, immediately yields indigo-blue (in the same state as from the indigo-vat); the filtered solution also continues to deposit indigo-blue when exposed to the air. According to Gerhardt, Fritzsche's chrysanilic acid is nothing but a mixture of isatin, indigo-white, and perhaps also other products resulting from the further action of the potash. The indigo-blue is formed by oxidation of the indigo-white.

Indigo-blue fused with *hydrate of potassium* yields first isatic acid, as above, then phenylcarbamic acid resulting from the decomposition of the latter. (Gerhardt.)

$$\underset{\text{Isatic acid.}}{C^9H^7NO^3} + H^2O = \underset{\substack{\text{Phenyl-car-}\\\text{bamic acid.}}}{C^7H^7NO^2} + CO^2 + H^2,$$

and by further decomposition, salicylic acid (Cahours) and phenylamine (Fritzsche):

$$\underset{\substack{\text{Phenyl-car-}\\\text{bamic acid.}}}{C^7H^7NO^2} + H^2O = \underset{\substack{\text{Salicylic}\\\text{acid.}}}{C^7H^6O^3} + NH^3$$

$$\underset{\substack{\text{Phenyl-car-}\\\text{bamic acid.}}}{C^7H^7NO^2} = \underset{\substack{\text{Phenyl-}\\\text{amine.}}}{C^6H^7N} + CO^2$$

13. Indigo-blue placed in contact with water, an *alkali*, and a *deoxidising substance*, becomes at first coloured green, and is then converted into indigo-white, which forms a yellow solution with alkalis. In this reaction, water is decomposed, the hydrogen being used in the formation of indigo-white, *e. g.* with *stannous oxide*:

$$\underset{\text{Indigo-blue.}}{2C^8H^5NO} + SnO + H^2O = \underset{\text{Indigo-white.}}{C^{16}H^{12}N^2O^2} + SnO^2$$

The following substances react in a similar manner: phosphorus, phosphorous acid, sulphurous acid, sulphydric acid, potassium-amalgam, sulphide of potassium, sulphide of sodium, sulphide of arsenic, sulphide of antimony, zinc, tin, iron, ferrous, stannous, and manganous oxides, grape-sugar, and substances undergoing fermentation or putrefaction, as sugar, gluten, urine, woad, madder. Warm putrid urine dissolves indigo-blue, the ammonia-compound of indigo-white being formed. According to Löwenthal, on the contrary (J. pr. Chem. lxx. 463), this reduction of blue to indigo-white is not produced by salts of sulphurous or phosphorous acid, by sulphide of potassium, sulphide of calcium, manganous salts, or arsenite of sodium; but indigo-blue dissolved in sulphuric acid is reduced to indigo-white, when mixed with excess of acid carbonate of potassium or sodium, and then treated with sulphydric acid. Löwenthal is of opinion that indigo-white is not indigo-blue *plus* hydrogen, but indigo-blue *minus* oxygen.

Testing and Valuation of Indigo.—Commercial indigo occurs in small lumps or cubic loaves of a violet-blue colour; when of good quality it is very light; assumes a coppery aspect when rubbed with a hard polished body; and is free from flaws or cavities traversed by brown or whitish veins. The best sorts are light enough to float on water.

External characters, however, give but very uncertain indications of the amount of real colouring matter contained in a sample of indigo; hence it becomes necessary to resort to chemical methods of estimating the amount of pure indigo-blue. Good sorts of indigo contain about 60 per cent., but the proportion is often much reduced by fraudulent admixture of foreign substances, such as sand, vegetable mould, powdered lead, starch, &c. Some foreign matters are also unavoidably introduced in the process of manufacture.

The indigo is first dried over the water-bath to estimate the hygroscopic water; which, in samples not fraudulently moistened, varies from 3·5 to 6 per cent. The dried indigo is then calcined in a platinum crucible to determine the amount of ash. Good indigo generally yields from 7 to 10 per cent. The presence of sand, lead-powder, &c., may then easily be detected by washing the ash with water.

The presence of starch, sometimes coloured with iodine, is indicated by the pale colour, greater density, and friability which it imparts to the lumps of indigo. It may be further detected by treating the indigo with slightly alkaline water, neutralising the filtered liquid with a few drops of acid, and testing with iodine.

The older methods of estimating the proportion of real indigo-blue in commercial indigo depend, for the most part, on the decoloration produced by chlorine and other oxidising agents.

1. *With chlorine water.*—A weighed quantity of the finely pulverised indigo is added by small portions to a measured quantity of a saturated aqueous solution of chlorine, as long as it dissolves with yellow colour, and the quantity thus dissolved is ascertained by weighing the residue. A similar trial is then made with perfectly pure indigo-blue,

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and a comparison of the two results gives the proportion of colouring matter sample of commercial indigo under examination. As the strength of the chlorin alters very quickly, it cannot be titrated long beforehand. (Berzelius.)

2. *With chloride of lime.*—The indigo is first dissolved by digestion for five hours at 50° or 60° with fuming sulphuric acid; the solution is thoroughly mix distilled water, and poured into a graduated burette, and from this vessel it is drop by drop to a measured quantity of aqueous chloride of lime, till the blue just becomes permanent. A similar experiment being then made with an equal of pure indigo blue, the colouring power of the two samples is in the inverse r the quantities of the blue solution consumed in the two experiments. (Schlumb Bull. Soc. industr. de Mulhouse, vol. xv.)

3. With *hydrochloric acid and chlorate of potassium.*—1 grm. of finely pul indigo is digested for some hours with 10 grms. of fuming sulphuric acid, agitati time to time to assist the solution. The liquid is then poured into a basin con a kilogramme of water, 50 grms. of strong hydrochloric acid are added, and th is heated to the boiling point. On the other hand, 0·25 grm. of chlorate of po is dissolved in 100 grms. of water; and the solution is poured into a graduated and added drop by drop to the boiling indigo solution till the blue colour cha red-brown. The richness of the sample of indigo is directly proportional quantity of chlorate consumed. (Bolley, Ann. Ch. Pharm. lxxv. 242.)

4. With *sulphuric acid* and *acid chromate of potassium.* The mode of pro is the same as that just described; 10 grms. of pure indigo-blue prepared by Fri method require for decoloration exactly 7½ pts. of the acid chromate. (Penny, Soc. J. v. 297.)

All these methods are liable to the objection that it is difficult to institute a comparison between the different shades of colour resulting from the oxidation indigo in different cases, the pure green tint thus produced in solutions of pure blue giving place to a dirty olive or brownish-green when crude indigo is used, sequence of the impurities contained in it. Moreover, in dissolving indigo in sulphuric acid, it is scarcely possible to avoid the formation of sulphurous a presence of which will of course raise the apparent percentage of indigo-blue sample. By employing these methods indeed, it is common to find, in a good sa indigo, more than 80 per cent. of pure indigo-blue, whereas the best qualities contain above 60 per cent., and average qualities not more than 40 to 50 per c

The following methods, which depend upon the reduction instead of the oxid the indigo, give more exact results.

5. With *Protosulphate of Iron.*—A weighed quantity of the finely pulverised i well mixed with an equal weight of pure lime previously slaked with water. The is poured into a stoppered bottle of known capacity, and the mortar is well rins water, which is added to the rest. The bottle is now heated in a water-bath for hours, and a quantity of finely-powdered sulphate of iron is added; the bottle filled up with water; the stopper is inserted; and, after the contents have b shaken, the whole is left at rest for several hours, till the indigo is reduced sediment has sunk to the bottom. A portion of the clear liquor is then drawn a siphon, and the quantity of liquid having been accurately measured, it is mix an excess of hydrochloric acid, and the precipitate, after having been oxidised posure to the air), is collected on a weighed filter, and washed with water. the filter with the indigo-blue is dried at the heat of the water-bath, and weigh the weight of the filter having been subtracted from that of the whole, the of the indigo-blue is ascertained. Suppose, for example, that the whole qua liquid was 200 measures, and that 50 measures have been drawn off, yielding 1 of indigo-blue; then the total quantity of indigo-blue in the sample is 40 grain 60 grains of indigo it is necessary to take from 1 lb. to 2 lbs. of water. This though rather tedious, gives better results than any of the preceding. The of indigo-blue indicated by it is usually somewhat less than the actual quant tained in the sample.

6. With *stannous chloride.*—The tin-solution is titrated with a solution indigo-blue, prepared by dissolving the substance dried at 210°–230° C. (410°– in 16 pts. of strong sulphuric acid, with addition of pounded glass to divide th and facilitate the solution. The indigo-solution thus obtained is diluted wit till a litre of it contains exactly 1 grm. of indigo-blue. The indigo to be exa then dissolved in a similar manner, and the titrated tin-solution is added to i burette till the blue colour changes through green to light-yellow. Iron, if pr the indigo, must first be removed by digestion in hydrochloric acid, with ad pounded glass. (E. Mulder, Scheik. Onderz. iii. [1] 37; Jahresber. 1860, p.

7. With *zinc.*—A solution of indigo in sulphuric acid is dilute with w hydrochloric acid, and decolorised by zinc in an atmosphere of carbonic anhyd

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then introduced into a graduated tube filled with
oxygen absorbed is read off after a few hours. A
pure indigo-blue, and the value of the commer-
son of the results.

ul, Ann. Chim. lxvi. 5; Berzelius, *Lehrb.* iii.
ance of uncertain composition, existing together
ndigo-red, in all kinds of commercial indigo. To
noved by treating the indigo with dilute sulphuric,
n with boiling water. On digesting the residue
e indigo-brown dissolves, together with a small
k-brown, almost black solution, from which, after
precipitated by an acid. The precipitate contains
e, from which it may be freed for the most part
ium, evaporating the filtrate to dryness, dissolving
undissolved portion, consisting chiefly of indigo-
h sulphuric acid.
a dark brown transparent resin, almost tasteless,
n, it yields ammonia and an empyreumatic oil.
y chlorine. It unites both with acids and with
brown compounds, easily soluble in water. The
, and the *lime-compound* insoluble. By boiling
excess, the indigo-brown may be separated and
ps one of the uses of lime in the indigo-vat

resemblance to Schunck's indihumin (p. 264),
ion of indican.

tance is extracted from crude indigo by treating
c, or acetic acid, then with boiling water, and
s a yellow, transparent extract, soluble in spirits
soluble in acid liquids. Its taste is like that of
distillation much ammonia and a fœtid oil, and
y vegetable gluten.

btained a green substance by adding potash in
ion of an alkaline hyposulphindigotate, till it
with a little alcohol, decomposing it with oxalic
acid by trituration with a little carbonate of
ing to dryness. The green solid residue thus
rming a green solution, which, when mixed with
e. It formed a green precipitate with acetate of
incture of galls. (Berzelius.)
stance from indigo, but it appears to have been
tle indigo-blue.

OPHŒNICIC ACID (p. 260).—The preparation of a
is described by L. and E. Boilley (Dingl. pol.
in this country by Johnson (Rep. pat. Invent.
sulphindigotate or sulphophœnicate of sodium.
is added to twenty times its weight of acid sul-
n, and the mixture is heated and stirred till a
ste thus produced is then intimately mixed with
d the colouring matter is precipitated by common
washed with water containing that salt. After
d silky crystals having a coppery lustre. (For
rics dyed with this preparation, see Rép. Chim.

nce occurring, together with indigo-gluten and
It was first noticed by Chevreul, afterwards more

n having been removed in the manner already
vith boiling alcohol of specific gravity 0·83. A
ich, when filtered and distilled, deposits indigo-
powder quite insoluble in water and in alkaline
, it yields a white crystalline sublimate (the so-
as unchanged indigo-red. Strong sulphuric acid
ution, which deposits nothing on addition of water.
wool, which at the same time acquires a dirty

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When the fresh leaves of *Polygonum tinctorium* are exhausted with ether, and part of the ether is distilled off, indigo-blue separates out; and on evaporating the remaining solution to dryness, and exhausting the residue with alcohol, filtering from a slight brown residue, again evaporating to dryness, and exhausting the residue with hot water, which extracts a little yellow colouring matter, a hard brittle friable resinous substance separates of a fine red colour, and probably agreeing essentially with the red of common crude indigo. It is insoluble in *water*, slightly soluble in *potash*, *ammonia*, and *acetic acid*, easily in *alcohol* and *ether*. The alcoholic solution turns red on addition of *baryta-water*, *lime-water*, *basic acetate of lead*, or *nitrate of silver*, and dark red with *stannous chloride*. With solution of *alum* it forms a beautiful red lake, not acted upon by alkaline carbonates.

The indigo obtained from the flowers of *Tankervillia cantonensis* contains a red substance, soluble in alcohol, but insoluble in water and in ether.

For further details respecting these indigo-reds, which are probably identical in the main with Schunck's indirubin (p. 268). See *Gmelin's Handbook*, xiii. 45.

INDIGO-SULPHURIC ACIDS. When indigo-blue is macerated in fuming sulphuric acid, heat is evolved, and a deep-blue solution is formed, called *sulphate of indigo*, *Saxony* or *composition-blue*, containing sulphindigotic acid, $C^8H^5NO.SO^3$. The liquid has a deep-blue colour, and may be diluted with water without becoming turbid; if, however, the sulphuric acid is not in excess, there generally remains a purple powder, consisting of sulphophœnicic acid, $2C^8H^5NO.SO^3$, insoluble in dilute acids, but soluble, with blue colour, in pure water. According to Berzelius, there is also formed a third acid, called hyposulphindigotic acid, which has not been analysed. The indigo-blue cannot be recovered from these acids by any known methods. Their solution loses its colour after a while, and is instantly turned yellow by a small quantity of nitric acid: this reaction is used in qualitative analysis for the detection of nitric acid.

Hyposulphindigotic acid. *Hyposulphocærulic acid.* To isolate this acid, the alcoholic solution of its ammonium-salt, obtained in the manner presently to be described (see SULPHINDIGOTIC ACID), is mixed with an alcoholic solution of acetate of lead; the whole is completely precipitated by addition of a little ammonia, and the precipitate is suspended in water and decomposed by sulphydric acid. A yellow liquid is then obtained, which, on exposure to the air, becomes blue, and is converted into hyposulphindigotic acid. By evaporating this solution, the acid is obtained as an amorphous mass, which becomes moist in contact with the air, dissolves readily in water, and reacts like sulphindigotic acid with sulphydric acid, zinc, iron, and charcoal.

The hyposulphindigotates resemble the sulphindigotates in many respects, but are distinguished by their solubility in alcohol of 84 per cent. When gently heated, they give off sulphurous anhydride without changing colour; at a higher temperature, they turn green and yield a sublimate of sulphite of ammonium.

The *ammonium-*, *potassium-* and *sodium-salts* are obtained by steeping wool dyed with sulphate of indigo in solutions of the corresponding alkaline carbonates, evaporating the resulting solutions to dryness, and exhausting the residues with alcohol, which takes up only the hyposulphindigotates.

The *aluminium-salt* resembles the corresponding salt of sulphindigotic acid.

The *barium-salt* is obtained by precipitating the potassium-salt with carbonate of barium, in dark-blue flocks, very soluble in pure water; the solution, when evaporated, deposits films having a coppery lustre.

The *calcium-* and *magnesium-salts* are very soluble in water and in alcohol.

The *lead-salt* is obtained by precipitating an alcoholic solution of the ammonium-salt with alcoholic acetate of lead. It is a blue powder, which dissolves slowly but completely in water: it is sparingly soluble in alcohol, and has an astringent taste.

Sulphindigotic Acid. $C^8H^5NO.SO^3$. *Sulphate of indigo*, *Soluble blue indigo*, *Sulphindylic acid*, *Sulphocærulic acid.*—Indigo may be dissolved in strong (monohydrated) sulphuric acid (SH^2O^4), as well as in the fuming acid (which contains sulphuric anhydride in solution), but it requires 15 pts. of the former, and only 6 pts. of the latter; moreover, the solution in common sulphuric acid requires the aid of heat, which gives rise to the formation of sulphurous acid; it may, however, be facilitated by triturating the indigo with pounded glass so as to divide the particles.

The acid solution is diluted with from 30 to 50 times its bulk of water; the liquid is filtered from the precipitated sulphophœnicic acid; the filtrate is digested at a gentle heat with wool or woollen stuff (previously prepared by washing, first with soap and then with water containing 1 per cent. carbonate of sodium, and finally with pure water), until no more colouring matter is taken up, the excess of sulphuric acid remaining in solution. The wool, dyed blue by sulphindigotic and hyposulphindigotic acids, is washed with water till the latter no longer becomes acid, and digested

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te of ammonium; the blue solution is poured off porated to dryness at 50°; and the residue is nt., which dissolves the hyposulphindigotate of tate. The latter is dissolved in water, and pre- rk-blue precipitate is washed with water, then y sulphydric acid; and the yellow or colourless ure to the air, is evaporated to dryness at 50° lphindigotate of ammonium is not effectually e by alcohol; it is better, therefore, to digest o long as it forms a precipitate with acetate of cid is not precipitated.

ms a solid mass having a peculiar agreeable k but decided acid reaction (Joss). It becomes *water* and in *alcohol*. It is separated from its and with greater facility by blood-charcoal, l by alkaline carbonates.

ut not by its salts, unless an acid is added, a com- d, being sufficient for the purpose. Boiling water portion of its colour, but alkalis remove it entirely completely decolorised by woollen stuffs; silk ur; linen and cotton take up very little. Silk y soap, but not by water. (Bergmann.)

acid yields by dry distillation sulphurous an- ch water, and a little empyreumatic oil. No t the sublimed sulphite of ammonia dissolves in d over a little of the undecomposed acid. The lty, but completely. The sulphindigotates also y dry distillation (Berzelius).—2. Sulphindi- o sunlight.—3. *Chlorine* produces a quantity of , and only a little chlorisatin and dichlorisatin e blue colour of the acid is changed to green by l to reddish-brown by *chlorate of potassium* and hindigotic acid is decomposed by *nitric acid*. y boiling with concentrated nitric acid and the cipitated by chloride of barium (Berzelius).— , heated with *chromate of potassium*, becomes rmanganate of potassium, it becomes first green ohr); when heated with *ferric salts*, it is deco- nn. Ch. Pharm., xxxiv. 235). These reactions cial indigo (p. 255).—6. *Deoxidising substances* nd derivable from indigo-white, and change the or *iron* filings dissolve in the solution without blue liquid, which, however, is decolorised by covers its blue colour on exposure to the air. the solution at ordinary temperatures; but on ulphur and becomes colourless. The decolora- ee acids. If the solution containing excess of vacuum over slightly moistened potash, a dark- h becomes moist and dark-blue on exposure to tic acid is likewise decomposed by *stannous* reductions, see *Gmelin's Handbook*, xiii. 60.)

$.SO^3$.—These salts are formed by direct com- They cannot be obtained crystallised; they are istre, and taste feebly saline and decidedly of s are slightly soluble in cold water, and more ue by reflected, and red by transmitted light.— decolorised than the free acid, by all substances the presence of free alkalis. *Protosulphate of* digotate, even on warming; not even when as to precipitate the protoxide of iron; but the mediate decoloration, and on the addition of e blue colour is restored. *Sulphide of potassium* the sulphindigotates, part of the sulphide being d solution appears yellow when neutral, and tral solution leaves, when evaporated in vacuo, a yellow when pulverised, and becomes blue on The solution turns blue on exposure to the air.

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Ferric and *cupric salts* instantly turn the solution blue, and are converted into salts of the lower oxides. The solution reduced by *stannous chloride* deposits, on exposure to the air, a white powder, which is a mixture of stannic oxide and a product of decomposition which becomes green on exposure to the air.

Sulphindigotates, when heated, give off water without melting. When strongly heated, they decompose, evolving free ammonia, carbonate of ammonium, cyanide of ammonium, a trace of volatile oil, and afterwards of carbonic anhydride, whilst a residue of metallic sulphide is left.

Sulphindigotate of Ammonium is prepared by the process described on page 258 (Berzelius); or by precipitating sulphindigotic acid, which should not be too dilute, with ammonia or a salt of ammonia (Crum). It reacts similarly to the potassium-salt. It melts when heated and swells up, but is not decomposed, even by a pretty strong heat, and although it assumes a charred appearance, still dissolves completely in water, forming a blue solution. When more strongly heated, it yields a sublimate of sulphite of ammonium (Berzelius.) It dissolves in from 40 to 50 parts of cold water, and in a much smaller quantity of hot water (Crum), and is precipitated from the solution by the alkaline sulphates and some other salts, but much less completely than the potassium-salt. It is not soluble in alcohol. (Crum, Berzelius.)

Sulphindigotate of Aluminium is readily soluble in water, and dries up like the other sulphindigotates on the evaporation of the solution. Sulphindigotate of potassium, mixed with a salt of aluminium and a little ammonia, throws down a dark blue pulverulent basic salt, becoming blackish-blue when dried. It gives up all its acid to an excess of alkali. (Berzelius.)

Sulphindigotate of Barium is precipitated in dark blue flakes, on mixing the potassium-salt with chloride of barium (Crum, Berzelius). It dissolves slightly in cold water with a bluish colour; more abundantly in hot water, imparting to it a dark colour. Owing to the great affinity of baryta for sulphindigotic acid, this salt is formed when hyposulphindigotate of potassium is mixed, first with sulphuric acid, and then with chloride of barium; an excess of sulphate of barium is, however, necessary to the reaction, and hence the precipitate has a paler colour. Sulphate of barium already precipitated likewise forms with hyposulphindigotate of potassium, a small quantity of sulphindigotate, and becomes pale blue.

Sulphindigotate of Calcium is soluble in water, but insoluble in alcohol, which precipitates it in blue flocks.

Sulphindigotate of Lead is precipitated in dark blue flocks, slightly soluble in water on mixing neutral acetate of lead with sulphindigotate of potassium. Basic acetate of lead forms a light blue precipitate, which becomes darker when dry.

Sulphindigotate of Magnesium is very soluble in water, and is not precipitated by an excess of sulphate of magnesium.

Sulphindigotate of Potassium, $C^8H^4KNO.SO^3$. This salt is obtained: 1. By steeping wool dyed blue with sulphate of indigo, in a solution of carbonate of potassium, evaporating the solution, and treating the residue with alcohol, which extracts hyposulphindigotate of potassium. The residue is then treated with acetic acid and alcohol to remove the excess of carbonate (Berzelius).—2. Indigo-blue is treated with excess of sulphuric acid; and after the sulphophœnicic acid has been removed by filtration, the blue liquid is saturated with acetate of potassium; the resulting blue precipitate is thrown on a filter, and washed with acetate of potassium till the liquid which runs through begins to turn blue; the salt is then washed with alcohol to remove the acetate. (Dumas.)

Sulphindigotate of potassium in the dry state, forms a copper-coloured mass, yielding a blue powder; blue also by transmitted light. It rapidly absorbs moisture from the air.

When heated it does not melt or evolve any purple vapours; it is difficult to incinerate. According to Berzelius, it forms sulphopurpurate of potassium when heated with lime-water out of contact with the air; in presence of air, it forms salts of sulphoflavic, sulphofulvic, and sulphorufic acids.

Sulphindigotate of potassium dissolves in 140 parts of cold water, and in a much smaller quantity of boiling water, a portion separating out on cooling. The solution is of a dark blue colour, transparent only when viewed in thin layers; when held up before the light of the sun or of a candle, it appears scarlet. 1 part of the salt imparts a blue colour to 500,000 parts of water. Water containing 1 per cent. of acetate of potassium does not dissolve the salt in the cold; on heating, a portion dissolves and separates out in blackish flakes on cooling. It is readily dissolved by sulphuric acid, but is not soluble in concentrated hydrochloric acid (Crum); or in alcohol of specific gravity 0·80. (Berzelius.)

If an aqueous solution of sulphindigotate of potassium is mixed with a barium- or

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calcium-salt and carbonate or phosphate of sodium added, carbonate and phosphate of barium and carbonate of calcium are precipitated of a light blue colour, and phosphate of calcium of a deep blue colour. When the solution of sulphindigotate of potassium is mixed with acetate of lead and a solution of tannic acid, the precipitate of tannate of lead carries down all the colouring matter with it.

Sulphindigotate of potassium occurs in commerce as paste or dry powder, known as precipitated indigo, indigo-carmine, soluble indigo, or solid blue. It is used for dyeing linen of an azure-blue colour, and for producing very pure blue colours on wool.

Sulphindigotate of Sodium, also called indigo-carmine, resembles the potassium-salt, and is used for similar porposes, but is more soluble in saline solutions.

Sulphophœnicic acid, $2C^8H^5NO.SO^3$. *Indigo-purple, Phœnicin, Sulphopurpuric acid.*—This acid is formed when sulphuric acid is allowed to act upon indigo for a short time, or not in excess. To prepare it 1 pt. of indigo-blue is mixed with from 8 to 10 pts. of strong sulphuric acid, and kept for three days at a temperature of 50° or 60°; the solution is then diluted with water, and the precipitate of sulphophœnicic acid is filtered, washed with dilute hydrochloric acid, and dried in an oil-bath at 80°—100° (Dumas). Or powdered indigo is purified by boiling with dilute sulphuric acid, and then shaken up with from 7 to 8 pts. of strong sulphuric acid till the mixture becomes olive-green. The whole is then diluted with a very large quantity of water, and the precipitate of sulphophœnicic acid is collected on a filter and washed with water, which becomes more deeply blue in proportion as the sulphuric acid is removed. The last filtrates are evaporated to dryness. (Crum.)

As the extraction of the sulphophœnicic acid on the filter according to (1) is a very slow process, and when the greater part of the indigo-blue is converted into sulphophœnicic acid by the prolonged action of the sulphuric acid, water will no longer pass through the filter, the following method may be employed, which yields a more abundant, though less pure product. 1 pt. of powdered indigo is shaken in a flask with 10 pts. of strong sulphuric acid, till the blue colour which the indigo had at first lost is completely restored. For this purpose, from ten to twelve hours are requisite at 7°, three hours in the heat of the sun, 20 minutes at 38°, and a few moments at 100°. A large quantity of water is added; the solution is filtered; and the precipitate is taken from the filter and washed by decantation with water containing sufficient chloride of ammonium to prevent it from dissolving the sulphophœnicic acid. The solution of chloride of ammonium is allowed to run from the filter, and the precipitate is removed and suspended in a large quantity of water. After three days, the solution is poured off, and the water is renewed as long as sulphophœnicic acid continues to dissolve. The sulphophœnicic acid is then precipitated from the decanted solutions by chloride of potassium, and the precipitate is washed on a filter with water as long as the water continues to pass through. Sulphophœnicic acid thus prepared contains a little potassium-salt and a large quantity of earthy matter; after drying, it is no longer soluble in water. (Crum.)

Häffely triturates 1 pt. of finely powdered indigo with 20 pts. of common sulphuric acid; allows the whole to stand for some time, till a drop of the solution, which is at first blue, colours water or paper violet; and then mixes the solution with a large quantity of water: the action of the sulphuric acid is promoted by heating the whole to 40°. If less sulphuric acid is used, it must be more strongly heated; if only 3 pts. of sulphuric acid are employed for 1 pt. of indigo, the latter is not completely converted into sulphophœnicic acid. If fuming sulphuric acid is used, it is not easy to discover when the reaction is ended.

Properties.—Sulphophœnicic acid forms a blue mass or a purple-red powder, soluble in water, to which it imparts a blue colour. It dissolves readily, with blue colour, in sulphuric acid, especially in the fuming acid, being at the same time gradually converted into sulphindigotic acid. With a large quantity of soda-ley, it forms a yellow solution which turns blue if immediately mixed with sulphuric acid of 66° B.; but stronger sulphuric acid added after 24 hours, produces a whitish precipitate. (Gros-Renaud, Dingl. pol. J. 129, 288.)

The *sulphophœnicates* are precipitated from the aqueous solution of the acid by the addition of other salts. When dry they are red; their aqueous solutions are blue. They dissolve very sparingly in water, but more readily in alcohol. The solutions are reduced to yellow liquids by heating with sulphydric acid, by sulphate of iron and lime, or by caustic alkalis. The reduced solutions turn blue on exposure to the air, and on the addition of other salts, the salt of sulphophœnicic acid is precipitated unchanged.

The *ammonium-salt*, when heated, evolves sulphurous anhydride together with sulphite of ammonium, and a red vapour which yields a sublimate like indigo-blue. This

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sublimate is often bright green on the lowest edges, like the wing-cases of cantharides, and turns brown when burnished.

The *potassium-salt*, $C^{16}H^9KN^2O^2.SH^2O^4$(?) is obtained by adding acetate of potassium to the aqueous solution of the acid. It is then precipitated in purple flocks, which must be washed, first with acetate of potassium, then with alcohol. It dissolves in 100 pts. of water.

The *sodium-salt* is obtained in like manner.

The solution of sulphophœnicic acid, even when very dilute, is precipitated by the salts of *calcium*, *magnesium*, *aluminium*, *iron*, *tin*, and *copper*.

Products obtained by decomposition of the Indigo-sulphuric acids.

The following products of the decomposition of these acids are described by Berzelius (*Lehrbuch der Chimie*, 4th Aufl. vii. 226); but their composition is very uncertain, and they require further examination:—

1. **Sulphoflavic acid.**—This acid is formed by heating sulphoviridate of potassium with lime-water in contact with the air.—To prepare it, sulphindigotate of potassium is heated with lime-water in an open vessel, until the solution acquires a pure red colour (if the action is too prolonged, it becomes yellow; if the access of air is kept under control, it is easier to hit the right moment). Carbonic anhydride is then passed through the liquid; the filtrate evaporated to dryness, and the green, brownish-yellow residue extracted with alcohol. The yellow solution is precipitated with acetate of lead; the lemon-yellow precipitate suspended in water and decomposed by sulphydric acid; and the solution filtered from the sulphide of lead is then left to evaporate. It forms yellow arborescent masses, having a strong acid taste and reaction. It is soluble in water and in alcohol; the solution forms with acetate of lead a lemon-yellow precipitate, insoluble in water.

2. **Sulphofulvic and Sulphorufic Acids.**—These acids are formed simultaneously with sulphoflavic acid. The residue, from which the sulphoflavic acid has been extracted by alcohol, is dissolved in water, and the bright-red solution is precipitated with basic acetate of lead. The pale-red precipitate is suspended in water, and decomposed with sulphydric acid, and the filtrate is evaporated to dryness. Absolute alcohol extracts from the residue, sulphofulvic acid, which, on evaporation, is deposited as a dark yellow, transparent mass, having the consistence of an extract; it forms a lead-salt, is readily soluble in water and in alcohol. The portion insoluble in alcohol is sulphorufic acid. This latter dissolves in water with a fine red colour, and, on evaporating the water, forms a dark red, opaque, amorphous mass, which tastes acid and strongly reddens litmus. The lead-salt is readily soluble in water and in alcohol.

3. **Sulphopurpuric Acid.**—This acid is formed by the action of alkalis upon sulphoviridic acid. 1 pt. of sulphindigotate of potassium is dissolved in 50 pts. of lime-water and heated in a covered vessel, till the solution, which has gradually turned purple red, does not become green again on cooling. After the whole has been allowed to cool in the covered vessel, the excess of lime is precipitated by carbonic acid; the filtrate is evaporated to dryness; and the residue treated with alcohol, which extracts a little sulphoflavic acid. The residue is dissolved in water, the purple-red solution precipitated with acetate of lead, and the precipitate suspended in water and decomposed by sulphydric acid; the filtered solution is then evaporated to dryness.

Sulphopurpuric acid forms a brown uncrystallised mass, dissolving in water with dark purple-red colour. The potassium-salt dissolves in water and imparts to it a dark purple-red colour, like that of permanganate of potassium. The precipitate produced by mixing the aqueous solution of the acid with acetate of lead, is slightly soluble in water, with a reddish colour; insoluble in alcohol. With excess of oxide of lead, a pale red salt is formed, which is insoluble in water.

4. **Sulphoviridic Acid.**—This is the first product of decomposition in the action of alkalis upon sulphindigotic acid.

1. To an alcoholic solution of an alkaline hyposulphindigotate, hydrate of potassium is added in small portions until it becomes green, and the green precipitate is washed on a filter with a little alcohol. The precipitate is decomposed by an aqueous solution of oxalic acid, filtered, and the filtrate is freed from excess of oxalic acid by triturating it with a little carbonate of calcium: it is then filtered and evaporated to dryness.

2. When a solution of hyposulphindigotate of barium is evaporated to dryness on a water-bath, it becomes green and yields a precipitate with basic acetate of lead, but not with the neutral acetate; and if the greyish-green precipitate is decomposed by sulphydric acid and the green filtrate evaporated to dryness, sulphoviridic acid is obtained as a dry, hard, gummy mass, having a strong acid reaction.

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It dissolves very readily in water, and slowly, but completely, in strong alcohol the solutions appear dark green by reflected light, and dark red by transmitted light. The aqueous solution mixed with lime-water becomes yellow in contact with the air. The *lead-salt* is somewhat soluble in water, imparting to it a greenish colour.

INDIGOTIC ACID. Syn. with NITROSALICYLIC ACID. (See SALICYLIC ACID.)

INDIGOTIN. Syn. with INDIGO-BLUE.

INDIGO-WHITE. $C^{16}H^{12}N^2O^2$. *White Indigo, reduced* or *deoxidised Indigo, Indigogen* (Gm. xiii. 93; Gerh. iii. 510).—A colourless substance, produced by the action of reducing agents on indigo-blue (pp. 251, 254), and differing from a double molecule of the latter ($C^{16}H^{10}N^2O^2$) by two atoms of hydrogen. Chevreul, who was the first to isolate it, supposed that it existed ready formed in indigoferous plants, and was converted into indigo-blue by oxidation; but Schunck has shown that this view is untenable, because indigo-white is soluble only in alkaline liquids, and the juice of plants is always acid. Moreover, if the indigo-white existed in the juice of these plants, it would be converted into indigo-blue by oxidation, on coming to the surface, which is not the case.

Preparation.—Commercial indigo, purified by boiling with hydrochloric acid, next with strong potash, and afterwards with alcohol, is mixed with freshly prepared hydrate of calcium (2 parts of quick-lime to 1 of indigo) and placed in a closed vessel with 150 parts of boiling water, after which sulphate of iron equal to one-third the weight of the indigo is added, and after the vessel has been closed, the whole is carefully shaken. After two days, the solution is decanted by means of a siphon into flasks filled with carbonic anhydride, and when the flasks are nearly full, they are completely filled with boiling dilute hydrochloric acid, corked up, and placed in a vessel containing cold water. The air is thus prevented from obtaining access to the indigo-white, which separates out in white crystalline flakes. After the indigo-white has settled down, the solution is drawn off with a wide siphon, and the deposit is thrown upon a filter, which is covered with a bell-jar, into which a stream of hydrogen or carbonic anhydride is passed. The filter is washed with cold water, which has been well boiled and then corked up. Indigo-white is very easy to wash, and if the deposit is allowed to stand for several days, it becomes so consistent that it may be washed in the air without becoming deeply coloured. After the contents of the filter have been washed, they are spread, while still moist, upon a glass plate and dried in a vacuum. When the indigo-white is dry, carbonic anhydride is allowed to flow into the receiver of the air-pump, in order that the pores of the dry mass may become filled with the gas (Berzelius, Dumas).—2. Three pts. of indigo-blue which have been purified by boiling, are digested for 24 hours with 5 pts. of hydrate of calcium, 4 pts. of sulphate of iron, and 120 pts. of water, in a closed flask filled with hydrogen, and the whole is frequently shaken till the deposit assumes a greenish-yellow and the solution a reddish-yellow colour. The lime is precipitated from the latter with carbonate of potassium, and the clear solution is decanted by means of a siphon filled with hydrogen, into a flask containing a mixture of hydrochloric acid and sulphite of ammonium. The thick white precipitate which is thus formed is filtered out of contact with the air, washed with water containing a little sulphite of ammonium, and dried at 100° in a stream of hydrogen. (Liebig.)

Properties.—Indigo-white thus prepared forms a coherent greyish-white mass having a faint silky lustre; if absolutely pure, it would probably be quite white. It is tasteless, inodorous, and does not change the colour of litmus. It is perfectly insoluble in *water*, and in such *acids* as do not decompose it, but dissolves in aqueous *alkalis*, in *alcohol*, and in *ether*, forming yellow solutions, which, when exposed to the air, turn yellow and deposit indigo-blue.

Decompositions.—1. When indigo-white is heated in a vacuum, a little water is evolved, a small quantity of indigo-blue sublimes, and a large carbonaceous residue is left (Berzelius).—2. When exposed to the *air*, and in contact with various *oxygen-compounds*, it takes up oxygen and is converted into indigo-blue. Freshly precipitated indigo-white turns blue immediately when shaken with water containing air, even if a free acid is present. After washing, and while still moist, it becomes purple through its entire mass on exposure to the air, unless it is rapidly dried. When dry, it requires several days' exposure to the air, to oxidise it completely, first becoming bright blue, and then dark blue through the entire mass. It cannot be preserved in sealed tubes, since the air contained in its pores is sufficient for its conversion into indigo-blue. Dry indigo-white exposed to the air at a gradually increasing temperature, suddenly becomes dark purple. When a *cupric salt* is added to an alkaline solution of indigo-white, a salt of the alkali, together with indigo-blue and cuprous oxide, are formed; the latter, on the addition of sulphuric acid, is decomposed into cuprous oxide, which dissolves, and a residue of metal.—3. Indigo-white precipitated from an alkaline

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solution by *nitric acid*, is turned blue by a slight excess of the acid, and then more completely decomposed (Berzelius). It dissolves instantly in *sulphuric acid*, and imparts to it a dark purple colour, which passes to blue on dilution. According to Berzelius, the indigo-white is oxidised, and part of the sulphuric acid converted into hyposulphuric acid.

Metallic Derivatives of Indigo-white.—Indigo-white dissolves readily in all aqueous *alkalis* and *alkaline earths*, also in the aqueous carbonates of ammonium, potassium, and sodium, and, according to Liebig, without depriving them of their alkaline reaction. The cold solutions are pure yellow, the warm and highly concentrated solutions brownish-yellow. When exposed to the air, they immediately deposit indigo-blue.

Indigo-white forms with *lime* a neutral compound, readily soluble in water, and a basic compound which is almost insoluble; this latter is precipitated when the solution of the more neutral body is digested with hydrate of calcium, or when indigo is digested with water, sulphate of iron, and excess of lime. The precipitate of gypsum and hydrated sesquioxide of iron, which is formed at the same time, may be readily suspended in water and separated by levigation. The basic compound is of a lemon-yellow colour, and very slightly soluble in water, to which it imparts a yellow colour. On exposure to the air, it first turns green, and then bright blue. (Berzelius.)

The alkaline solutions of indigo-white are precipitated by the salts of the *earth-metals* and *heavy metals*, yielding white precipitates, which turn blue in the air more quickly than indigo-white itself. The *magnesium-compound*, being slightly soluble, is partly thrown down as a white precipitate, and partly remains dissolved in the aqueous solution, to which it imparts a yellow colour; it turns blue on exposure to the air. The *aluminium-compound* is white, but rapidly turns blue on the filter; if it be then dried, it forms a dark blue crystalline powder which sparkles in sunshine; indigo-blue may be very readily sublimed from it, and a grey earthy residue then remains. (Berzelius.)

The *manganous compound* is dirty-green, and does not yield any sublimate of indigo-blue when dried in the air and heated. The *zinc-compound* is white, but rapidly turns blue on exposure to the air, and then yields a sublimate of indigo-blue when heated. The *lead-compound* is white and slightly crystalline, turns rapidly blue on exposure to the air, and if then heated, detonates slightly, and yields reduced lead. The *ferrous compound* is white, but quickly turns blue on exposure to the air; if it be *then* heated, it does not yield any sublimate of indigo-blue. The *cobalt-compound* is grass-green, and after drying in the air, does not yield any sublimate of indigo-blue when heated. Nitrate of *silver* produces with an aqueous solution of the potassium-compound a precipitate which is at first transparent brown, and then becomes black; it is not acted upon by the air, but when heated, produces a gentle explosion and yields a sublimate of indigo-blue and a residue of metallic silver. (Berzelius.)

INDIGO-YELLOW. A substance produced by heating hyposulphindigotate of calcium with lime-water, in contact with the air. It is a transparent yellow mass, with neutral reaction; swells up when heated, emitting an odour like that of burnt animal matter, and is slowly converted into a combustible cinder. It dissolves in water and in alcohol, forming yellow solutions. The aqueous solution is precipitated incompletely by neutral acetate of lead, completely by the basic acetate.

INDIHUMIN. A product of the decomposition of indican (p. 248) perhaps identical with indigo-brown. It is obtained but sparingly, and not on all occasions. It is a brown powder, containing 62·86 per cent. carbon, 4·71 hydrogen, 7·19 nitrogen, and 25·24 oxygen, agreeing nearly with the formula $C^{16}H^9NO^3$. It burns without melting when heated, is insoluble in water and in alcohol, but dissolves in aqueous alkalis, forming a brown liquid, from which it is precipitated by acids. It dissolves in boiling nitric acid, forming a yellow solution, which, on evaporation, leaves an orange-yellow residue.

INDIN. $C^{16}H^{10}N^2O^2$. (Laurent, Ann. Ch. Phys. [3] iii. 471.)—A compound, probably containing the elements of two molecules of indigo-blue, produced by the action of potash on isatyde, sulphisatyde, or disulphisatyde by heating isatan or isatyde:—

$$\underset{\text{Isatan.}}{C^{16}H^{12}N^2O^2} = \underset{\text{Indin.}}{C^{16}H^{10}N^2O^2} + H^2O.$$

$$\underset{\text{Isatyde.}}{2C^{16}H^{12}N^2O^4} = \underset{\text{Indin.}}{C^{16}H^{10}N^2O^2} + \underset{\text{Isatin.}}{2C^8H^5NO^2} + 2H^2O.$$

$$\underset{\text{Isatyde.}}{2C^{16}H^{12}N^2O^4} + 3KHO = \underset{\text{Indin-potassium.}}{C^{16}H^9KN^2O^2} + \underset{\text{Isatate of potassium.}}{2C^8H^6KNO^3} + 3H^2O.$$

$$\underset{\text{Sulphisatyde.}}{2C^{16}H^{12}N^2SO^3} + 3KHO = C^{16}H^9KN^2O^2 + 2C^8H^6KNO^3 + H^2O + 2H^2S.$$

$$\underset{\text{Disulphisatyde.}}{2C^{16}H^{12}N^2S^2O^2} + 4KHO = C^{16}H^9KN^2O^2 + 2C^8H^6KNO^3 + KHS + 3H^2S.$$

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ction of potash on disulphisatyde. This substance
oured upon it so that a stiff magma is formed,
nd potash added drop by drop. When after five
oloured, alcohol is gradually added, and the whole
se-coloured paste is formed, which is diluted with
s washed, first with alcohol, and then with water.
abundance of sulphisatyde, the water is removed
h is allowed to run through the filter; the indin is
d with very strong lukewarm potash, wherein it
which after a few hours becomes thick with black
potash is too hot, the black colour disappears, and
It is then diluted with absolute alcohol, and the
crystals are washed on a small filter with common
ric acid, and finally with water; they are thus
indin. In order to obtain indin crystallised, the
absolute alcohol, and the boiling solution is mixed
crystals then separate out on cooling.
owder or fine microscopic needles; insoluble in
hol and *ether*, even at the boiling heat. When
gins to melt, yields a sublimate of needle-shaped
uantity of charcoal. It dissolves with red colour
unchanged by water. With *nitric acid*, it yields
ndin.
ferent times, do not agree very well together, the
er cent., and the hydrogen from 3·0 to 4·65; the
be 11·0 per cent. The formula $C^{16}H^{10}N^2O^2$ re-
The differences arose, according to Laurent, from
a portion of the indin had been converted by the

N^2O^2. This compound is formed in the prepara-
may be prepared in a state of greater purity by
ol, and dissolving it in strong alcoholic potash.
ken from the fire, deposits black crystals, which
cantation, rapidly washed with absolute alcohol,
vacuum on a porous tile. The crystals rapidly
resolved into potash and indin. The compound
per cent. potassium, whereas the above formula
s agree better with the formula $C^{16}H^{11}KN^2O^3$,
an acid, related to indin in the same manner as
NO^2.

ivatives of Indin.

rdmann, J. pr. Chem. xxii. 265. Laurent, Ann.
-1. By the action of bromine on indin (Laurent).
mann).—3. By the action of bromine upon disul-

with bromine, whereupon hydrobromic acid is
formed (Laurent). Or dibromisatyde is heated
, and dibromisatin and undecomposed dibromi-
by treating them with boiling alcohol (Erdmann).
tyde, whereupon hydrobromic acid and bromide
brown mass thus formed is treated with ether,
ellow crystalline mass, and leaves dibromindin as

a violet-black powder; prepared according to 2,
ble in *alcohol* and in *ether*.
en two platinum crucible-covers, the greater part
lds a sublimate of shining copper-coloured laminæ,
light under the microscope. It blackens when
and the whole boiled, the dibromindin gradually
on, from which acids precipitate yellow flakes.
id hydrate of potassium, a blackish red solution is
oric acid precipitates violet-coloured dibromindin.

mann, J. pr. Chem. xxii. 264.)—Produced from
by treating it with potash.
the product is freed from chlorisatin and un-

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decomposed chlorisatyde by boiling alcohol. Or, chlorisatyde is dissolved in warm potash, and allowed to cool: the mother-liquor is poured off from the deposit of chlorisatate of potassium, and mixed with acetic acid, which precipitates yellow chlorisatic acid. On subsequently heating the filtrate with hydrochloric acid, it assumes a deep orange colour, and deposits violet flakes of chlorindin, which are filtered from the hot solution.

Chlorindin forms a dirty violet powder, insoluble in water, hydrochloric acid, and *alcohol*. It dissolves in *potash*, forming a yellowish solution, with which hydrochloric acid gives a yellow precipitate, soluble with yellow colour in water.

Tetrachlorindin. $C^{16}H^{8}Cl^{4}N^{2}O^{2}$. (Erdmann, *loc. cit.*)—Produced from chlorisatyde by the action of heat below 200°, or by the action of potash. It resembles chlorindin.

Hydrindin. $C^{32}H^{22}N^{4}O^{5}$? (Laurent, Ann. Ch. Phys. [3] iii. 475.)—A compound produced by the action of alcoholic potash upon indin, isatin, isatyde, sulphisatyde, or disulphisatyde.

Preparation.—1. Indin moistened with alcohol is warmed with strong potash-ley till the solution, which is at first black, has become colourless, and the crystals of hydrindin-potassium, which separate out on cooling, are completely freed from potash by water.—2. When isatyde is treated with potash and a little alcohol, a beautiful rose-coloured solution is formed, which, when mixed with hydrochloric acid, and gently evaporated, becomes yellow, and deposits on cooling a mixture of isatin and hydrindin, from which the isatin is extracted by treating with a little boiling alcohol. —3. Sulphisatyde dissolves completely in gently heated potash, and on cooling, the potassium-compound of hydrindin sometimes separates out in beautiful small, pale-yellow crystals; sometimes, however, the solution solidifies into a mass of needles having a silky lustre. The whole is mixed with a large quantity of water, and the crystals are washed on a filter till all the potash is extracted. The filtrate mixed with hydrochloric acid still deposits a small quantity of hydrindin, together with a substance which is perhaps indin.

Hydrindin forms a white or pale-yellow powder, insoluble in *water*, slightly soluble in boiling *alcohol*, and separating from the solution on cooling, in small rhombic or six-sided needles.

Hydrindin carefully heated above 300°, turns violet-brown and gives off 2 at. water; the residue behaves with alcoholic potash like indin.—With boiling nitric acid it forms a violet powder similar to nitrindin.

Hydrindin contains, according to the mean of Laurent's analyses, 69·80 per cent. C, 4·85 H, and 10·70 N. The formula, $C^{32}H^{22}N^{4}O^{5}$, deduced therefrom by Laurent, which represents hydrindin as composed of 2 at. indin + $H^{2}O$, requires only 4·0 per cent. H, which is much below the analytical number. Gerhardt suggested the formula $C^{32}H^{22}N^{4}O^{4}.H^{2}O$, which requires 70·59 per cent. C, 4·41 H, and 10·29 N, and represents hydrindin as a hydrate of a double molecule of indin + 2 at. H. The formation of hydrindin by the action of potash on indin, &c. is more favourable to Laurent's than to Gerhardt's view, provided hydrindin is the sole product of the reaction; but in reality other products are formed at the same time, so that the formation of the more highly hydrogenised compound, hydrindin, may perhaps be compensated by that of one or more compounds containing a larger proportion of oxygen. The organic molecule, $C^{16}H^{12}N^{2}O$, associated with the elements of sulphuric acid in Schlieper's hydrindinsulphuric acid (p. 267) differs from indin by the substitution of 2 at. H for 1 at. O; but as the mode of formation of this molecule is altogether different from that of Laurent's hydrindin, it is probable that the two have little more in common than the name.

Hydrindin-potassium. $C^{32}H^{21}KN^{4}O^{5}.3H^{2}O$? When hydrindin is dissolved in warm aqueous potash, this salt separates out in short, brilliant, pale-yellow prisms or silky needles, containing, according to Laurent's analysis, 60·0 per cent. C, 4·3 H, 5·6 K, and 9·0 water of crystallisation; these numbers agree better with Laurent's formula above given, which requires 60·54 per cent. C, 4·27 H, and 6·18 K, than with that which corresponds to Gerhardt's formula of hydrindin, viz. $C^{32}H^{21}KN^{4}O^{4}.3H^{2}O$ which requires 62·11 C, 4·37 H and 6·34 K. The salt is decomposed by washing with water, leaving nothing but hydrindin.

Nitrindin. $C^{16}H^{8}N^{4}O^{6} = C^{16}H^{8}(NO^{2})^{2}N^{2}O^{2}$. (Laurent, Ann. Ch. Phys. [3] iii. 478.)—Produced by boiling indin or hydrindin with nitric acid. Isatyde and sulphisatyde probably also yield nitrindin when boiled with nitric acid.

It is a bright violet powder, insoluble in water, very slightly soluble in alcohol and ether.

It decomposes rather quickly when heated in closed vessels, and leaves a residue of bulky charcoal, which glows even out of contact with the air. It is gradually decomposed by boiling *nitric acid*. It dissolves in *potash*, forming a deep brown solution,

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from which hydrochloric acid throws down sometimes undecomposed indin, and sometimes yellow flakes, especially if the solution has been boiled. With *sulphite of ammonium* it behaves like indin. Ammonia does not act upon it.

INDINSULPHURIC ACID. $C^{16}H^{12}N^2S^2O^9 = (C^{16}H^{10}N^2O^2.SO^3).SH^2O^4$. (G. and A. Schlieper, Ann. Ch. Pharm. cxx. 24.)—An acid produced by the oxidation of hydrindinsulphuric acid (see below). The transformation may be effected by heating hydrindinsulphuric acid with a few drops of nitric acid, or by treating it with an alkaline of solution of ferricyanide of potassium or hypochlorite of sodium. The hydrindinsulphates are also converted into indinsulphates by exposure to the air, especially in alkaline solution, or by heating them with nitric or nitromuriatic acid. The mother-liquor obtained in the preparation of hydrindinsulphate of barium, treated with hot nitric acid, yields large quantities of the indinsulphate. The free acid may be obtained in the crystalline form by decomposing the barium-salt with sulphuric acid, and evaporating the filtrate. It has a red colour, is easily soluble in *water*, sparingly in *alcohol*, and is precipitated from the alcoholic solution by *ether*, in red flocks. The aqueous solution dyes silk and wool scarlet. Its colour is altered by *alkalis*, probably in consequence of a change analogous to the conversion of isatin into isatic acid. By *sulphydric acid* it is reduced to hydrindin-sulphuric acid:

$$C^{16}H^{12}N^2S^2O^9 + 2H^2S = C^{16}H^{14}N^2S^2O^8 + S^2 + H^2O.$$

Indinsulphuric acid is dibasic, and appears to form soluble salts with most bases. The salts when heated yield a crystalline sublimate of a fine red colour.

The *barium-salt*, $C^{16}H^{10}Ba''N^2S^2O^9.2H^2O$, is obtained, by drenching the hydrindinsulphate with dilute ammonia, exposing it to the air, and stirring frequently, as a finely crystalline powder of a fiery carmine-red colour; or, by heating the mother-liquor of the hydrindinsulphate with nitric acid, as a light powder consisting of slender dark-red, brown needles. It is moderately soluble in pure water, insoluble in aqueous chloride of barium, alcohol, and cold hydrochloric acid and nitric acids. At 100° it gives off 6·45 per cent. water (calc. 2 at. = 5·89), and the dried salt yields by analysis 33·64 per cent. carbon, 2·02 hydrogen, and 26·27 to 26·74 baryta, the formula requiring 33·39 C, 1·74 H, and 26·60 BaO.

The *potassium-salt*, $C^{16}H^{10}K^2N^2S^2O^9.5H^2O$, is obtained, by oxidising the solution of the hydrindinsulphate, by exposure to the air, or by means of ferricyanide of potassium, as a bulky carmine-coloured precipitate, perfectly insoluble in liquids containing potash. A hot solution of indinsulphuric acid mixed with excess of a potassium-salt, the chloride for example, deposits the indinsulphate on cooling in interlaced needles of a dark-red colour and almost metallic lustre, and so bulky that they nearly fill the liquid. The air-dried salt heated to 100° gave off, on the average, 14·24 and 14·34 per cent. water (calc. 5 at. = 14·85), and the remaining anhydrous salt gave by analysis 18·09 and 18·21 per cent. K^2O, the formula requiring 18·21 per cent.

The *silver-salt*, $C^{16}H^{10}Ag^2N^2S^2O^9$, is obtained by mixing a solution of the acid with excess of nitrate of silver, in small brown bulky needles yielding (at 100°) by analysis 29·39 per cent. C, 1·58 H, and 32·76 Ag; calc. 29·36 C, 1·53 H, and 33·02 Ag.

Hydrindinsulphuric acid. $C^{16}H^{14}N^2S^2O^8 = (C^{16}H^{12}N^2O.SO^3).SH^2O^4$. (G. and A. Schlieper, Ann. Ch. Pharm. cxx. 20.)—This acid, which may be derived from indinsulphuric acid by the substitution of 2 at. H for 1 at. O,* is produced by the action of sulphydric acid or sulphide of ammonium on indinsulphuric, or isatinsulphuric acid; also of zinc and hydrochloric or sulphuric acid on the latter, but not by the action of hydriodic acid.

Preparation.—A moderately concentrated solution of isatinsulphuric acid (1 pt. of the acid to 5 or 6 pts. water) is slightly supersaturated with ammonia, then mixed with half its bulk of sulphide of ammonium, and heated to boiling, the liquid then becoming brown from dissolved sulphur, and smelling strongly of ammonia. More sulphide of ammonium is then gradually added to the boiling liquid, till it smells permanently of sulphydric acid; and the boiling is continued (in a flask, to prevent oxidation) as long as a trace of ammonia escapes. The neutral pale-red solution filtered from the separated sulphur consists almost wholly of hydrindinsulphate of ammonium, which may be converted into the barium-salt by precipitation with chloride of barium, and from this the acid is obtained by decomposition with sulphuric acid.

Hydrindinsulphuric acid is obtained, by evaporation of its aqueous solution, as a colourless radio-crystalline mass, which becomes reddish when exposed to the air. It has a very sour taste, dissolves easily in *water*, less easily in *alcohol*, and is insoluble in *ether*.

The acid is dibasic; its salts are almost all soluble, and are easily converted into indinsulphates by oxidation, especially in alkaline solutions.

* In the original memoir (p. 31), the two acids are said to be related to one another in the same manner as indigo-white and indigo-blue; but this statement is inconsistent with the formulæ.

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The *barium-salt*, $C^{16}H^{12}Ba''N^2S^2O^8.4H^2O$ (air-dried), is a light crystalline powder consisting of white shining scales. At 100° it gives off 11·68 per cent. water (calc. 11·37 per cent.), and the anhydrous salt yields by analysis 26·96 and 26·87 per cent. Ba^2O, the formula requiring 27·27 per cent.

Leucindin-sulphuric acid. $C^{16}H^{18}N^2S^2O^{10}$. (G. and A. Schlieper, Ann. Ch. Pharm. cxx. 33.)—This acid, which differs from the last by the elements of one molecule of water, is also produced by the action of sulphide of ammonium on isatinsulphuric acid. If in the process above described, the liquid, after filtration from the sulphur, be immediately mixed with excess of caustic baryta, instead of being evaporated, the whole of the ammonia then expelled by boiling, the excess of baryta removed by carbonic acid, and the clear yellowish solution strongly concentrated by evaporation, it deposits, after standing for a few days, white crystalline crusts of leucindin-sulphate of barium, which when recrystallised, forms hard, colourless, shining crystals containing $C^{16}H^{16}Ba^2S^2O^{10}$, with probably 5 at. water. They gave off 11·65 per cent. water at 100°, and 14·3 per cent. at 120° (mean 12·97); by calculation 5 at. = 13·1. The anhydrous salt gave by analysis (mean) 28·10 per cent. C, 3·85 H, and 22·14 Ba^2O; calculation 27·94 C, 3·78 H, and 22·27 Ba^2O.

By decomposing the barium-salt with sulphuric acid, and evaporating the filtrate, leucindin-sulphuric acid is obtained as a white crystalline mass, having a very sour taste, easily soluble in water, sparingly in alcohol. Its alkaline solutions are not reddened either by exposure to the air, or by treatment with oxidising agents. The solution of the barium-salt is not precipitated by nitrate of silver; but on adding ammonia, a white flocculent precipitate is formed, which turns brown when warmed; acetate of lead forms a red precipitate. The barium-salt evaporated down with hydrochloric or sulphuric acid, is converted into indinsulphate of barium; it is not altered by heating with potash.

INDIRETIN. $C^{18}H^{17}NO^5$. (Schunck, Phil. Mag. [4] xv. 29, 117.)—A compound, produced, together with indihumin, indirubin, and other products, by the action of dilute sulphuric acid upon indican (p. 248). It is a dark-brown shining resin, which at 100°–190°, contains on the average 66·04 per cent. C, 5·57 H, 3·83 N, and 24·56 O (calc. 66·05 C, 5·19 H, 4·28 N, and 24·48 O).—When *heated* on platinum foil, it melts, burns with a yellow, smoky flame, and leaves charcoal. By *dry distillation* it gives off strong-smelling vapours, and yields an oily distillate. It dissolves in *oil of vitriol* with brown colour, and chars when heated. With boiling *nitric acid*, it forms resin, and picric acid.—It dissolves easily in aqueous *alkalis*, and with brown colour in *ammonia*, being precipitated therefrom by *barium*, *calcium*, and *silver-salts*. It is precipitated from the alcoholic solution by *neutral acetate* of *lead*, and partially by *cupric acetate*.

INDIRUBIN. C^8H^5NO. (Schunck, *loc. cit.*)—A compound, isomeric with indigo-blue (p. 249), and perhaps identical with indigo-red (p. 257), obtained in small quantity by decomposition of indican, more abundantly from Indian woad-leaves, by immersing them in a boiling alkaline solution of stannous chloride, the liquid then depositing indirubin on exposure to the air. The product thus obtained is purified by dissolving it in alkaline stannous chloride, and treating it, after reprecipitation, with caustic soda, acids, and water, and then recrystallised from alcohol. It forms long, purple, metallic-shining needles, which appear red by transmitted light, and when heated volatilise in red vapours and sublime. In the impure state, it is a brown-red amorphous powder. Contains 72·78 per cent. C, 10·50 N, 4·16 H, and 12·56 O, agreeing with the formula above given. It dissolves with purple colour in *strong sulphuric acid*, and is partially precipitated therefrom by water. Cold *nitric* acid dissolves it with purple colour, but on applying heat, decomposition takes place, attended with formation of resin and picric acid. It is but slightly altered by a mixture of *chromate of potassium* and dilute *sulphuric acid*, even at the boiling heat. With *chlorine* under water, it forms a blue amorphous resin soluble in alcohol. Heated with *soda-lime*, it gives off an odour of benzoin, together with alkaline vapours, which partly condense to needles. It is insoluble in aqueous alkalis, but dissolves easily on addition of *stannous chloride* or *grape-sugar*. From the yellow solution, acids throw down dirty yellow flocks, which acquire a purple colour on exposure to the air, and impart a fast purple dye to cotton-wool immersed in the liquid and afterwards exposed to the air. It is not precipitated from the alcoholic solution by ammoniacal *sugar-of-lead*. Its sulphuric acid solution imparts a fine colour to wool, cotton, and silk.

INDIUM. A metal recently discovered by F. Reich and Th. Richter (J. pr. Chem. lxxxix. 441) in the zinc-blende of Freiberg. Its spectrum is characterised by two indigo-coloured lines, one very bright and more refrangible than the blue line of strontium; the other fainter but still more refrangible, approaching the blue line of potas-

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peculiar spectrum that led to the discovery of the
f blende, galena, and arsenical pyrites, was roasted
eated with hydrochloric acid, and the solution was
e chloride of zinc thus obtained, exhibited, when
first of the indigo lines above mentioned. The
a state of greater purity, and from this the hydrate
The first line then came out with much greater
ise observed.
l in very small quantity only, so that its properties
The metal itself is of a lead-grey colour, soft,
ke lead. It dissolves easily in hydrochloric acid,
rom the solution of this salt, it is precipitated by
nsoluble in excess of either reagent. Sulphydric
id solution. The oxide heated on charcoal with
h when reheated oxidises to a yellowish powder.
violet tint to the flame of a Bunsen's burner. (See

L. See ELECTRICITY (ii. 384, 451).
See MAGNETISM.
ICAL. See LIGHT, CHEMICAL ACTION OF.
UE. (Gerh. iii. 509.)
xperiments on the influence of infusoria in exciting
Pasteur (Compt. rend. lvi. 416; Rép. Chim. p.
ate of calcium mixed with a few thousandths of
ne and earthy phosphates (either artificially pre-
f infusoria), was placed in a flat-bottomed bottle,
ented to a bent glass tube; the bottle was then
ater heated to the boiling point, while the end of
er likewise heated to boiling; by this means all
out. The surface of the water in the vessel into
then covered with a thick layer of oil, and the
ty-four hours. Not the slightest trace of fermen-
t on quickly introducing into the bottle a small
ontaneous fermentation of tartrate of calcium, and
uantity of water thereby dislodged, with water
the end of the tube below the surface of mercury
the infusoria multiplied rapidly in the deposit of
pletely, being replaced by a deposit consisting of

ation of the tartrate is determined by the presence
oxygen. If the bottle is filled up with aërated
aneously, and the infusoria multiply quickly, re-
the last trace, and replacing it by a slightly larger
e ferment finds the nitrogen and phosphates re-
buminous matter present or the ammoniacal salts
arbon is supplied by the tartaric acid. (See FER-

the germination of plants, see Lemaire, Compt.
pp. 1863, p. 371.
ompt. rend. xxxviii. 932; Jahresber. 1855, p. 649),
infusoria and algæ goes on only when they can
ly in the state of chemical combination, *e.g.* as
atters, or in the form of ammonical salts. They
ith atmospheric air continually renewed, but die if
onia and organic matters by washing with oil of

Jahresber. 1854, p. 145; 1855, p. 134), the green
ally identical with chlorophyll.
infusorial earth situated on the southern edge of
has been analysed by W. Wicke (Ann. Ch. Pharm.
rs, the upper, which is from 10 to 18 feet thick,
te when dry, and the lower, which is 10 feet thick,

SiO^2	Ca^2CO^3	Fe^4O^3	Al^4O^3		
87·86	0·75	0·73	0·13	=	100·18
74·48	0·34	0·39	—	=	99·64

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INK. Every liquor or pigment used for writing or printing is distinguished by the name of ink. Inks are of various colours, but the black and red are most in use, both for writing and printing. We shall first speak of *writing inks*, which consist either of a coloured and not too thin liquid, or a finely divided coloured precipitate suspended in a liquid.

1. Black inks.—Common black ink for writing is made by adding an infusion or decoction of nut-galls to a solution of copperas (ferrous sulphate). The infusion or decoction of the galls contains both gallotannic and gallic acids, both of which produce deep-black precipitates with ferric salts, but with ferrous salts, white precipitates which turn black by oxidation on exposure to the air. Moreover, gallic acid colours ferric salts of a much deeper black than gallotannic acid; hence it is advantageous to leave the infusion to itself for some time, either before or after mixture with the iron-salts, in order that the tannic acid contained in it may be converted into gallic acid (ii. 767, 768).

To retain the precipitate in suspension, and prevent it from forming a sediment, a certain quantity of gum is always added: the gum likewise gives a certain gloss to the ink. These are the essential ingredients of good writing ink, and any other colouring matters added, for the sake of cheapness, as substitutes for a portion of the galls, only impair its quality. Logwood is sometimes used, for the sake both of the tannin and the colouring matter which it contains.

To prevent ink from becoming mouldy, various substances are added to it, such as essential oils, finely bruised cloves, a few drops of phenic acid, and sometimes (but not advantageously) corrosive sublimate. The addition of an acid retards the conversion of the ferrous into ferric salt; the ink then remains thinner and pale while kept in the bottle, and becomes darker only as the writing dries.

The following are some of the numerous recipes for the preparation of black ink, calculated for 1,000 pts. of water:—

	a	*b*	*c*	*d*	*e*	*f*	*g*
Galls	225	187	133	125	66	62	31
Copperas	75	73	55	24	22	31	19
Gum-arabic	25	73	55	24	19	31	8

	h	*i*	*k*	*l*	*m*
Galls	50	174	50	60	42
Logwood	—	—	100	20	21
Copperas	32	87	16	20	21
Sulphate of copper	—	—	—	—	5
Gum	9	43	47	20	16
Sugar	—	—	23	1000	
Vinegar	125	135	—	—	—

Of the genuine inks (*a*—*g*), *a*, *b*, and *c* are too strong for ordinary use; *d*, *e* and *f* are perhaps the best; *g* would be somewhat too pale. The rest cannot be recommended, excepting for special purposes. Sulphate of copper deepens the colour of the precipitate, but renders it more compact and heavy, and therefore more apt to settle down. A certain quantity of sugar renders the ink more fluid, and permits the addition of a larger proportion of gum. It likewise renders the ink adhesive when dry, so that a copy of the writing may easily be taken off by laying a sheet of thin unsized paper, damped with a sponge, on the written paper, and passing lightly over it a flat iron very moderately heated: ink of this quality is called copying ink.

The so-called alizarin-inks (a mere commercial name, by no means implying that they contain the alizarin of madder) consist of common ink mixed with a little free sulphuric acid, which, like other acids, retards the oxidation of the ferrous precipitate (see IRON, OXIDES OF), so that the writing becomes black only after exposure to the air; the change being, perhaps, accelerated by the neutralisation of the sulphuric acid by the basic substances contained in the paper; the ink blackens very quickly when exposed to ammoniacal vapours. A certain quantity of sulphindigotic acid (p. 258), or its sodium-salt (indigo-carmine) is usually added, so that the ink may not appear too pale in writing. An ink of this kind may be prepared by exhausting 40 pts. by weight of nut-galls with 112 pts. water, and then adding 7 pts. copperas and ¼ pt. oxalic acid. At the same time, 1 pt. of finely pulverised indigo-blue is dissolved in 4 pts. fuming sulphuric acid; the solution after 24 hours is diluted with water, and mixed with a small quantity of carbonate of soda; the precipitate is collected, washed to remove the saline solution, then suspended in water; and this liquid is added to the former till the whole exhibits a rather deep greenish-blue colour.

Chrome ink.—Runge first suggested the preparation of ink with logwood and chromate of potassium. Such ink is more easily diluted than ordinary copperas-ink, and is not liable to turn mouldy; but on the other hand, it soon becomes viscid and

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gelatinous. Runge prepares it by mixing 16 pts. by weight of solid commercial extract of logwood, with 1,000 pts. water (or a decoction of 1 pt. of logwood boiled down to 8 pts. of liquid), and adds 1 pt. of yellow chromate of potassium dissolved in water. Göbel takes 24 pts. of solid logwood extract, 1,000 pts. water, and 2 pts. yellow chromate.

Vanadium ink.—Prepared by mixing a decoction of galls with vanadate of ammonia. It is black, and flows easily, because it does not contain any precipitate; it is not attacked by dilute alkalis, but acids turn it blue. (Berzelius.)

The *black-violet Rouen ink* (*encre bleue rouenaise*) is prepared by boiling 750 pts. of logwood with 6,000 pts. water, 35 pts. alum, 31 pts. gum-arabic, and 15 pts. sugar-candy, leaving the mixture to stand for two or three days, and straining through a linen cloth.

Ink in cakes.—42 pts. of good nut-galls and 3 pts. of madder are boiled in about six times their weight of water; the filtered decoction is mixed with 5½ pts. copperas, and 2 pts. pyrolignate of iron; 1½ pts. solution of indigo (in sulphuric acid, diluted with water) is then added; the mixture is evaporated nearly to dryness at a gentle heat, and with constant stirring; and the pasty mass is then made into cakes, and thoroughly dried. This ink dissolved in 6 pts. of hot water is said to make an excellent copying ink, and in 10 or 12 pts. water, a very fine writing ink.

Ink-powder.—A solid chrome-ink may be made by triturating together to a fine powder, 100 extract of logwood, 1 pt. neutral chromate of potassium, and $\frac{1}{10}$ indigo-carmine. 1 pt. of this powder added to 32 pts. water is said to make very good ink. A mixture of 4 pts. pounded galls, 2 pts. copperas, and 1 pt. gum-arabic is also frequently sold as an ink-powder.

Copying inks.—Inks for this purpose must be rather thick, not dry too quickly, and soften when moistened again, without becoming too fluid. The following preparation is much recommended: 4 pts. by weight of logwood-extract are dissolved in a mixture of 60 pts. vinegar, and 70 pts. water, and 3 pts. copperas, 2 pts. alum, 2 pts. gum-arabic, and 4 pts. sugar are then added. This ink is at first more violet than the Rouen ink, which is also used as a copying ink.

Indelible inks.—As writing executed with ordinary ink is liable to fade in course of time, the tannate and gallate of iron being gradually decomposed, and as, moreover, it is easily effaced by the action of certain chemical reagents (oxalic acid, hydrochloric acid, chlorine), it is desirable that valuable documents should be written with an ink not liable to destruction from such agencies. Various compositions have been proposed for this purpose. Most of them consist of common ink, or some other dark-coloured liquid in which finely divided carbon (Indian ink or lamp-black) is suspended. The simplest of all is made by mixing common ink with Indian ink (p. 246) rubbed up with weak hydrochloric acid. Writing executed with such ink cannot be bleached by chlorine or destroyed by acids; but the carbon may be ultimately removed by water, even when it is as finely divided as in Indian ink, and consequently penetrates the pores of the paper to a certain extent. Ink prepared in like manner with lamp-black is easily washed away. Traill's indelible ink is prepared by steeping wheat-gluten in water for 24 to 36 hours, then dissolving it with aid of heat, in strong vinegar, of specific gravity 1·033, or in pyroligneous acid, and then rubbing it up with Indian ink or lamp-black. This ink is of a fine black colour, and cannot be obliterated by water, chlorine, or dilute acids. Kind dissolves 1 pt. honey in 14 pts. water, adds 2 pts. strong sulphuric acid, and then adds a quantity of indigo-solution sufficient to render the ink visible in writing. A hot iron is then passed over the writing, whereby not only the honey is carbonised, but likewise a portion of the paper-fibre, by the action of the free sulphuric acid. The writing cannot be effaced by any chemical reagent, and only with great difficulty by mechanical means, since the ink penetrates deeply into the paper, and the charcoal is consequently separated within the pores; the paper is, however, very much attacked.

The vanadium-ink, above described, may also be used as an indelible ink; acids merely turn it blue; chlorine destroys the black colour, but does not efface the writing, even after long washing.

Red Ink.—Red ink is usually prepared either with cochineal or with Brazil-wood. The *cochineal inks* are the brightest, but at the same time the dearest and most fugitive. The best is a solution of pure carmine in caustic ammonia; it must be preserved in well-stopped vessels. Böttger recommends 1 pt. of good carmine, 120 caustic ammonia, and 1½ pt. gum-arabic. A cheaper but less brightly coloured ink is made by drenching 12 pts. of pulverised cochineal and 4 pts. of carbonate of ammonia (or pearl-ash) with 32 pts. hot water, then digesting and pouring off the clear liquid. Addition of cream of tartar and stannic chloride renders the ink more scarlet; cream of tartar and an equal weight of alum give it a crimson tint.

Brazil-wood inks are made by boiling the wood in water, adding tin-salt (stannous chloride) or cream of tartar and alum to modify the tint, and thickening with gum-

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arabic; *e.g.* 4 pts. Brazil-wood boiled in 60 pts. water, the decoction boiled 36 pts., filtered, and mixed with $\frac{1}{8}$ pt. of tin-salt and $\frac{1}{4}$ pt. gum-arabic; Brazil-wood, boiled with 2 pts. alum and 2 pts. cream of tartar in 120 pts. wa liquid concentrated to 6 pts. by weight, and mixed with 2 pts. gum-arabic a sugar.

Blue inks.—The best is made by dissolving 30 pts. pure Prussian blu blue, ii. 227) in a solution of 4 pts. oxalic acid in 1,000 pts. water. A blue ink be prepared by dissolving 4 pts. of indigo-carmine in 64 pts. water, and m with 1 pt. gum arabic; but it cannot be used with steel pens.

Yellow and green inks are sometimes, though very rarely, used. The for be made with decoction of saffron or yellow berries; the latter of solution of mixed with turmeric or gamboge; or better of indigo-carmine mixed with pi It may also be prepared from the green modification of chrome-alum, namely solving 3 pts. acid chromate of potassium in 8 pts. water, adding 1 pt. alcol sulphuric acid by drops, and heating till the liquid assumes a brownish green then diluting with 16 pts. water, adding a few more drops of sulphuric acid the liquid to stand, and adding a small quantity of gum-arabic.

Sympathetic inks.—This name is applied to inks which make characters till brought out by heat or the application of some reagent. If a weak of *galls* be used, the writing will be invisible till the paper is moistened with solution of sulphate of iron. Dilute solutions of *gold* and *silver* remain c upon the paper till exposed to the sun's light, which gives a dark colour to the and renders them visible. Most *acids*, or *saline solutions*, diluted, and used with, become visible by heating before the fire, which concentrates them, and their action on the paper. Dilute *prussiate of potash* affords blue lette wetted with solution of sulphate of iron. The solution of *cobalt* in aq when diluted, affords an ink which becomes green when held to the disappears again when suffered to cool. This ink has been used in fanciful dra trees, the green leaves of which appear when warm, and vanish again on cool the heat be continued too long after the letters appear, it renders them per If oxide of cobalt be dissolved in acetic acid, and a little nitre added, the solut exhibit a pale rose colour when heated, which disappears on cooling. A of equal parts of sulphate of copper and sal-ammoniac gives a yellow colo heated, that disappears when cold.

Sympathetic inks have been proposed as the instruments of secret corresp but they are of little use in this respect, because their properties change by rema the paper for a few days; most of them have more or less of a tinge when th dry, and none of them resist the test of heating the paper till it begi scorched.

Marking inks.—Inks for marking linen must be able to withstand the water, soap, alkaline leys and acid liquids. The best are those which contai They consist of a solution of nitrate of silver, usually coloured with sap-green, colouring matter, sometimes with lamp-black, and thickened with gum. It is prepare the part of the linen to be marked with a solution of carbonate of gum, then smooth it with a hot iron, and after writing upon it, expose it shine. The writing may be effaced by a solution of cyanide of potassium without iodine.

Roder (Polyt. Notizblatt, 1856, p. 112) prepares a marking ink by dissolvi molybdic oxide in hydrochloric acid, adding 240 pts. water, 6 pts. gum-ara 2 pts. liquorice-juice. The writing is to be dried and then moistened with so stannous chloride. Inks containing gold or platinum have also been recon for this purpose, but they are too costly for general use.

An ink for writing on *zinc plant-labels* may be made by dissolving equ acetate of copper and sal-ammoniac in distilled water. When characters are with this solution on a zinc plate, the copper is precipitated, forming deep bl durable marks.

Ink for marking *copper* and *silver* vessels may be made by boiling sul antimony in strong potash-ley, leaving the liquid to cool, and filteri separated kermes. As this liquid does not act upon iron, steel pens may be writing with it on the metal. The characters on copper and silver are black durable; on tin, lead, and zinc, less durable.

Printing ink.—All inks or paints used for letter-press, copper-plate, lith printing, &c. consist essentially of well-boiled drying oils (varnishes) mixed wi black, or other pigment, according to the colour intended to be produced. S resinous matters are sometimes added to give the boiled oil the required consi

The oil most frequently used for the preparation of the varnish is linseed oil is also used in localities where it can be had cheap; but it loses more w

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boiling than linseed oil, and does not easily acquire so firm a consistence. The oil should be old and well cleared, by deposition. from particles of mucus.

Ten or twelve gallons of the oil are set over the fire in an iron pot, capable of holding at least half as much more; for the oil swells up greatly, and its boiling over into the fire would be very dangerous. When it boils, it is continually stirred with an iron ladle: and if it do not itself take fire, it is kindled with a piece of flaming paper or wood: for simple boiling, without the actual inflammation of the oil, does not communicate a sufficient degree of the drying quality required. The oil is suffered to burn for half an hour or more, and the flame being then extinguished by covering the vessel close, the boiling is afterwards continued with a gentle heat, till the oil appears of a proper consistence; in this state it is called varnish.* It is necessary to have two kinds of this varnish, a thicker and a thinner, from the greater or less boiling, to be occasionally mixed together as different purposes may require, that which answers well in hot weather being too thick in cold, and large characters not requiring so stiff an ink as small ones.

The thickest varnish, when cold, may be drawn into threads like weak glue, by which criterion the workmen judge of the due boiling, small quantities being from time to time taken out and dropped upon a tile for this purpose. It is very viscid and tenacious, like the soft resinous juices, or thick turpentine. Neither water nor alcohol dissolves it; but it mingles readily enough with fresh oil, and unites with mucilages into a mass diffusible in water in an emulsive form. The oil loses from one-tenth to one-eighth of its weight by boiling into the thick varnish.

For letter-press printing ink, the addition of soap to the varnish is indispensable, to enable the ink to be taken up clearly from the types by the moistened paper, without smearing. The soap used for the purpose is yellow resin-soap; it is cut into thin slices, well dried, rubbed to coarse powder, and incorporated by small portions at a time with the varnish, which is then once more placed over the fire, to expel any remaining moisture.

The colouring matter of black printing ink is the best lamp-black, previously calcined to free it from empyreumatic oils and resins. Its somewhat brownish colour is corrected by the addition of a little Prussian blue or indigo.

The ink used by copper-plate printers differs in the oil, which is not so much boiled as to acquire the adhesive quality. This would render it less disposed to enter the cavities of the engraving, and more difficult either to be spread or wiped off (Ure).† The black is likewise of a different kind. Instead of lamp-black, or sublimed charcoal, the Frankfort black is used, which is a residual or denser charcoal, said to be made from vine-twigs. Lamp-black is said to give a degree of toughness to the ink, which the Frankfort does not; but the goodness of the colour seems to be the leading inducement for the use of the latter.

For red, blue, and yellow printing inks, the ordinary linseed oil varnish is not very well adapted, as its brown colour impairs the brightness of the tint. A good varnish for the purpose may be made by mixing copaïba balsam (previously subjected to rapid boiling with water for several hours in an open dish, to render it more tenacious, and diminish the unpleasant odour) with $\frac{1}{20}$ to $\frac{1}{10}$ of its weight of pulverised white curd soap, then warm the mixture a little, and incorporate it with the pigment previously rubbed to fine powder with spirit of wine, and dried. For the lighter colours, it is best to mix very deep-coloured pigments with a considerable quantity of carbonate of magnesia. In that case, light-coloured linseed-oil varnish mixed with $\frac{1}{20}$ white soap may be used. A fine red is formed of vermillion mixed with $\frac{1}{10}$ carmine, and $\frac{1}{4}$ magnesia. Blue is given by ultramarine (the darkest varieties used in calico-printing) with magnesia; yellow by chromate of lead. Prussian blue mixed with chrome-yellow and a large quantity of magnesia, or ultramarine with chromate of zinc, yields a fine green. Browns are obtained with bistre and sepia.

Lithographic printing ink is made in the same way as common printing ink, but with a larger proportion of lamp-black, and without addition of soap. (See LITHOGRAPHY.)

For further details on printing inks, see *Handwörterbuch der Chemie*, vii. 388, and *Ure's Dictionary of Arts*, &c. iii. 530.

* The description of the process given in the text is taken from *Ure's Dictionary of Chemistry* (3rd ed. 1851). Mr. Savage also, in his work on the *Preparation of Printing Ink* (London, 1832) says that good varnish for printing ink cannot be made without allowing the oil to burn. The German practice appears, however, to be somewhat different; for in the *Handwörterbuch der Chemie* (Bd. vii. p. 391) it is stated that the oil should be heated only till the vapour which rises from it can be set on fire with a piece of burning paper, but will cease to burn of itself after a little while, or at least will be easily extinguished by putting on the cover; further, that if this temperature be exceeded, there is great danger of the oil getting into a state of violent combustion, which cannot be extinguished even by covering the vessel, and may occasion an enormous loss of oil.

† In the *Handwörterbuch der Chemie* (vii. 399) it is stated, on the contrary, that ink for copper-plate printing is prepared with the thickest linseed-oil varnish, which has been allowed to burn.

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INOCARPIN. A red colouring matter contained in the juice of *Inocarpus edulis*, a tree growing in Tahiti. The juice which exudes from incisions in the bark of young trees, or the pericarp of green fruits, is colourless, but soon turns red on exposure to the air (the juice of old trees is red as soon as it runs out), and dries up to a red gummy mass, soluble in water and in alcohol, insoluble in ether. The aqueous solution mixed with caustic alkalis exhibits a peculiar play of colours when shaken up with air. The reddened juice contains also a yellow colouring matter called xanthocarpin. (Cuzent, J. Pharm. xxxv. 241.)

INOSIC ACID. $C^5H^8N^2O^6$ (?) (Liebig, Ann. Ch. Pharm. [3] xxxiii. 129.)—An acid found in the mother-liquor of the preparation of creatine from flesh-juice. When this mother-liquor is concentrated, then mixed with alcohol till it acquires a milky consistence, and left to itself for a few days, it deposits a crystalline mixture consisting of creatine, inosate of potassium, inosate of barium, and various substances of unknown composition. The crystals are redissolved in hot water, and chloride of barium is passed into the solution, which then, on cooling, deposits crystals of inosate of barium; and this salt, decomposed by sulphuric acid, yields inosic acid.

Inosic acid is uncrystallisable, easily soluble in water, and has a very agreeable flavour of broth. Alcohol precipitates it from its aqueous solution. It is insoluble in ether. It does not precipitate barium- or calcium-salts, but with copper-salts it forms a bluish-green precipitate, insoluble in boiling water. With lead-salts it forms a white precipitate; and with silver-salts, a white gelatinous precipitate, having the aspect of alumina, soluble in nitric acid and in ammonia.

Inosic acid, heated with peroxide of lead and a small quantity of sulphuric acid, is decomposed, and the filtered liquid contains needle-shaped crystals. The *inosates*, heated on platinum-foil, decompose, giving off an odour of roast meat.

Inosate of potassium forms elongated quadrilateral prisms, very soluble in water, insoluble in alcohol. It gives off 22·02 per cent. of water at 100°, and the dried salt contains 20·7 per cent. potash. The *sodium-salt* crystallises in small silky needles, very soluble in water; insoluble in alcohol. The *barium-salt* forms elongated quadrilateral scales, having a nacreous lustre. 3,000 pts. of water at 16° dissolve 2·5 pts. of this salt; it is insoluble in alcohol. A solution, saturated at 70°, deposits part of the salt when raised to the boiling heat. The crystals, dried at 100°, contain 24·5 to 24·8 per cent. C, 2·6 H, 11·4 N, 31·1 to 33·8 O, and 30·4 BaO; whence Liebig deduces the formula $C^5H^6Ba^2N^2O^6.\frac{1}{2}H^2O$. Gerhardt considers the composition to be more correctly represented by the formula $C^5H^7BaN^2O^6.3H^2O$. The crystals effloresce in the air, giving off 19·07 per cent. water,

Inosate of copper is nearly insoluble in water and in acetic acid; very soluble in ammonia. *Inosate of silver* is sparingly soluble in pure water, and does not blacken by exposure to light.

INOSITE. $C^6H^{12}O^6$. *Inosin. Phaseomannite.* (Scherer [1850], Ann. Ch. Pharm. lxiii. 322; lxxxi. 375.—Vohl, *ibid.* xcix. 125; ci. 50.—Cloetta, *ibid.* xcix. 289.—W. Marmé, *ibid.* cxxix. 222.)—A saccharine substance isomeric with glucose, discovered by Scherer in the muscular substance of the heart (hence its name, from ἶς, ἰνός, muscle), and since found to exist in the lungs, kidneys, liver and spleen of oxen (Cloetta), also in the brain (W. Müller); in the human kidneys and in the urine, in a case of Bright's disease: at most to the amount of 0·1 per cent. It occurs also in several plants, having been obtained from green kidney beans, the unripe fruit of *Phaseolus vulgaris* (Vohl); from the green pods and unripe seeds of the garden pea (*Pisum sativum*); the unripe fruit of the lentil (*Ervum lens*), and of the common acacia (*Robinia pseudacacia*); from the heads of the common cabbage (*Brassica oleracea*, var. *capitata*); from the herb of foxglove and from extract of digitalis; from the leaves and stems of dandelion (*Taraxacum dens leonis*), not from the flowers or roots; from the shoots of the potato; from the green herb and unripe berries of asparagus; and from two cryptogamous plants, *viz. Lactarius piperatus*, L., and *Clavaria crocea*, Pers. (Marmé.)

Preparation.—From organs of the animal body. 1. The muscle of the heart, or other organs containing inosite, is exhausted with water, as for the preparation of creatine; the phosphates are precipitated from the liquid by baryta-water; the filtrate is evaporated; and the creatine allowed to crystallise out. The mother-liquor is treated with dilute sulphuric acid to remove the dissolved baryta, and, after removal of the sulphate of barium, heated as long as volatile acids escape. It is then, in order to remove the last traces of volatile acids and of lactic acid, repeatedly shaken up with ether as long as anything is dissolved. The liquid, separated from the ether, is mixed with alcohol till a turbidity begins to appear; then, after standing for some time, it is poured off from the precipitated sulphate of potassium, and mixed with more alcohol, whereby crystals of inosite mixed with sulphate of potassium are obtained. The crystals of the former are picked out and dissolved in a small quantity of warm water, which leaves the more difficultly soluble sulphate of potassium, and are purified by

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recrystallisation (Scherer).—2. The fresh-chopped tissue is covered with water, and allowed to stand for 24 hours in a cool place, with frequent stirring; the liquid is then separated, and the residue pressed; the solution is heated with a little acetic acid to separate albumin and hæmatin, then strained, evaporated on the water-bath to one tenth, precipitated with neutral acetate of lead, and filtered; and the filtrate is mixed with basic acetate of lead, whereupon inosite is thrown down in combination with oxide of lead, accompanied by uric acid, cystine, and other substances. The precipitate, after washing, is decomposed under water by sulphydric acid, and the liquid filtered from the sulphide of lead; it then sometimes deposits crystals of uric acid, and when evaporated to a small bulk on the water-bath, and mixed with alcohol till a turbidity is produced, it yields crystals of inosite (Cloetta). Acetate of lead may also be added at once to the water used for making the extract (W. Müller).—3. The liquid from which the inosite is to be separated is concentrated by evaporation, and mixed, boiling, with three or four measures of alcohol; if a large precipitate, which sticks to the bottom, is thus produced, the liquid is poured off hot; but if only a slight, not sticky precipitate is produced, the hot solution is filtered through a previously heated funnel, and left to stand for 24 hours; crystals of inosite are then deposited, and are washed with a small quantity of cold alcohol. If the precipitate caused by hot alcohol is dissolved in a small quantity of boiling water, and treated like the first solution, a further quantity of inosite is obtained. In case no inosite separates from the cooled solution, the crystallisation may be facilitated by addition of ether until a turbidity remains after shaking. (Cooper Lane, Ann. Ch. Pharm. cxvii. 118.)

From kidney beans and other vegetable organs.—The fruit cut up in the bean-mill is hung in a pressing bag for half an hour in boiling water, or in steam, whereby it becomes possible to press it; the expressed liquid is then evaporated to a syrup on a water-bath, and alcohol is added till a permanent turbidity is produced. The crystals which form are purified by repeated crystallisation from water, with help of animal charcoal. (Vohl.)

Marmé, after freeing the aqueous extracts of the plants above mentioned from everything precipitable by tannic acid and neutral acetate of lead, and decolorising them as completely as possible with milk of lime or animal charcoal, precipitated them with basic acetate of lead; mixed the filtrate with ammonia, whereby a second precipitate was obtained; decomposed both precipitates with sulphydric acid; concentrated the filtrate on the water-bath till it became turbid on addition of alcohol; then mixed it with a double volume of alcohol; warmed the liquid till it became clear; and left it to itself for several days, adding a little ether if necessary, as in Cooper Lane's method. The sulphide of lead sometimes obstinately retains small quantities of inosite, which can only be removed by boiling with water.

Properties.—Inosite is deposited from its concentrated aqueous solution in crystals containing 2 at. water, $C^6H^{12}O^6.2H^2O$. According to Vohl, the crystals are tabular, like those of gypsum; according to Scherer, they are oblique prisms, arranged for the most part in groups like cauliflower-heads; according to Cloetta, they are right rhombic prisms with angles of 138·52° and 41·8°. Specific gravity = 1·1154 at 5° (Vohl). In dry air, in vacuo over sulphuric acid, or at 100°, they become white and opaque, and give off their water, leaving anhydrous inosite, $C^6H^{12}O^6$, as a white efflorescd mass, which melts at a temperature above 210°, yielding a colourless liquid, which solidifies in the crystalline state when quickly cooled, and to an amorphous mass when cooled slowly, but does not lose weight or undergo further alteration (Scherer). Anhydrous inosite separates in white, opaque crystals from the aqueous solution cooled below 0°. (Vohl). Inosite has a pure sweet taste and no rotatory power.

Hydrated inosite dissolves in 6 pts. *water* at 19° (Vohl), in 6½ pts. at 24° (Cloetta). The concentrated solution, of specific gravity 1·0548 at 19°, is not syrupy and not subject to spontaneous decomposition. Inosite is slightly soluble in cold aqueous *alcohol*, more soluble at the boiling heat; insoluble in absolute alcohol and in *ether*.

Inosite does not combine with *chloride of sodium* or *chloride of potassium*, these salts crystallising out unaltered from its aqueous solution. The aqueous solution forms, with *basic acetate of lead*, a precipitate which appears to contain $C^6H^{12}O^6.2Pb^2O$.

Decompositions.—1. After dehydrated inosite has been melted above 210°, it swells up when more strongly *heated*, and evolves gas which burns with a pale blue flame; it is afterwards charred, and then burns with a brightly luminous flame, leaving an easily combustible cinder (Scherer). When quickly heated, it gives off vapours which excite tears and produces a smell of burnt sugar (Vohl).—2. Aqueous inosite is not affected by *ozone* (Gorup-Besanez, Ann. Ch. Pharm. cx. 103).—3. The solution of inosite in dilute *nitric acid* does not give off nitrous acid till moderately concentrated; after evaporation to dryness, it contains oxalic acid. The aqueous solution of the residue, freed from oxalic acid by carbonate of calcium, deposits on standing magnificent purple-red

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flocks, soluble in dilute acids and precipitable without alteration by ammonia (Vohl). When aqueous inosite is evaporated nearly to dryness with nitric acid, and the residue is moistened with ammonia and a small quantity of solution of chloride of calcium, and again evaporated, a rose-red substance remains. This reaction affords a delicate and characteristic test of the presence of inosite (Scherer, Vohl). Inosite dissolves without evolution of gas, in cold or boiling nitric acid of specific gravity 1·52, forming a solution whence oil of vitriol precipitates nitro-inosite (Vohl).—4. Inosite dissolves without coloration in *sulphuric acid*, either cold or at 100°; is not blackened till more strongly heated, and then evolves sulphurous anhydride (Vohl). It is not altered by boiling with dilute *acids* (Scherer, Vohl).—5. It may be boiled with concentrated *potash-ley*, or with *baryta-water*, without alteration or coloration (Scherer, Vohl).—6. The aqueous solution mixed with *cupric sulphate*, yields, on addition of potash-ley, a bluish green precipitate which quickly disappears on addition of excess of potash. No cuprous oxide separates from the solution in boiling, but a light blue precipitate falls when the liquid is left to stand for several days (Scherer). Aqueous inosite yields, when heated with *potassio-cupric tartrate*, a green solution, whence a bulky green precipitate separates, the supernatant liquid again becoming blue. After removing the precipitate, the filtrate shows the same change of colour when heated (Cloetta). According to Vohl, the change of colour which occurs on heating the deep azure-blue mixture of inosite and potassio-cupric tartrate, is not very striking, and is due, as well as the production of the precipitate, to the presence of traces of foreign substances.—7. Inosite is not capable of undergoing vinous fermentation (Scherer). In contact with *cheese*, *flesh*, or decaying *membrane*, and chalk, it undergoes lactous fermentation, carbonic, lactic, and butyric acids being formed. (Scherer, Vohl.)

Nitro-inosite. $C^6H^6N^6O^{18} = C^6H^6(NO^2)^6O^6$. *Inosine hexnitrique.* (Vohl, *loc. cit.*)—This compound is obtained by dissolving anhydrous inosite in nitric acid of specific gravity 1·52, and precipitating the solution with sulphuric acid. The product, which, according to the temperature attained by the mixture, separates either as a powder or as oil-drops which solidify to crystalline masses, is well washed with water and recrystallised from boiling alcohol. It forms rhombohedrons, often some lines in length; melts to an oil when heated, and solidifies to an amorphous mass which becomes crystalline after a few days. It is permanent in air, either dry or moist; insoluble in *water*, easily soluble in *alcohol*.

Nitro-inosite deflagrates without residue when quickly *heated*, and detonates under the hammer. It is decomposed when warmed with concentrated acids. It dissolves, with dark brown colour and evolution of ammonia, in cold or warm *potash-ley*. The alkaline solution precipitates cuprous oxide from *potassio-cupric tartrate*, and a mirror of metallic silver from *ammonio-nitrate of silver*. Nitro-inosite treated with *nitric acid*, *ammonia* and *chloride of calcium*, shows the coloration of inosite.

INSOLINIC ACID. See TEREPHTHALIC ACID.

INTESTINAL CONCRETIONS. These concretions are of rare occurrence in man and in carnivorous animals, but occur more frequently in herbivorous animals, especially in horses. They exhibit great diversity in their properties and composition, as well as in their origin. Many owe their origin to an albuminous exudate or blood-coagulum, which is retained in the intestine, and gradually solidified by resorption of the soluble portion. These stones consist mainly of coagulated fibrin mixed with calcium-salts and remains of food, and sometimes containing a foreign body as nucleus. In a concretion of this kind from the intestine of a child, Davy found 74 per cent. fibrin, 19 per cent. of other organic matters, and 7 per cent. inorganic salts.

A second kind of intestinal concretion consists chiefly of earthy salts, calcic phosphate and carbonate, ammonio-magnesic carbonate, and magnesic carbonate mixed or unmixed with remains of food; such stones often contain a foreign nucleus. They are most frequent in vegetable feeders, especially in horses, and often attain a weight of several pounds. A concretion from the cœcum of a cart-horse, analysed by F. Simon, was spherical, perfectly smooth, greyish-yellow, weighed 12½ oz., and consisted of three layers, deposited round a fragment of granite. All three layers consisted of ammonio-magnesian phosphate, with a small quantity of alkaline phosphates, but no phosphate of calcium. The middle layer exhibited a radiating structure from the centre outwards, with woody fibres interposed in like manner amongst the stony mass. In 100 pts., Simon found 81·11 ammonio-magnesian phosphate, and 1·5 per cent. alkaline phosphates.

Children examined stones from the colon of a man, which weighed from 500 to 1,000 grms., and consisted of plum-stones, surrounded by a smooth compact mass made up of alternate layers of earthy phosphates and ligneous matter.

The formation of these stones is due to the precipitation of earthy salts originally

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dissolved in the food, and their subsequent agglomeration by intestinal mucus, or round a foreign body.

A third kind of intestinal concretion consists chiefly of undigested residues of food; such stones have usually a woody consistence, and are formed round a foreign body. Laugier examined a concretion of this kind from the rectum of a man; it consisted of a nucleus of bone, surrounded by interlaced vegetable fibres, from which water extracted 14 per cent. of animal matter having a fæcal odour, together with small quantities of sal ammoniac and chloride of calcium.

Another class of intestinal concretions consists of fatty matters mixed with small quantities of fibrin and calcium-salts. Lassaigne analysed a number of small concretions of this kind voided by a girl suffering from tuberculosis. They contained 74 per cent. fatty matters (for the most part free fatty acids, perhaps oleic and stearic), 21 animal matter, 4 phosphate of calcium, and 1 chloride of sodium.

Bezoar-stones (i. 584) must also be classed amongst intestinal concretions. (Handwörterbuch d. Chem. 2te Aufl. ii. [3] 374.)

INTESTINAL JUICE. The mucous secretion of the pouch-like glands of the intestinal canal (the Lieberkühnian glands of the small intestine and the follicles of the colon). When viewed by the microscope, it exhibits granulated cells and cell-nuclei, and, as commonly obtained, likewise small quantities of fat and epithelium. When filtered from these matters, it forms a tolerably clear, mucous, strongly alkaline liquid, which does not coagulate by heat, and is not precipitated by acetic acid, nor, when mixed with that acid, by chloride of barium. When mixed, however, with eight or ten times its volume of alcohol, it deposits white flocks, which dissolve easily and completely in water; the solution thus obtained is not precipitated by hydrochloric, sulphuric, or acetic acid, or by mercuric chloride, but gives precipitates with the neutral and basic acetates of lead.

The constituents of pure intestinal juice are the same as those of mucus. In 1,000 pts. of the filtered intestinal juice of a dog, Schmidt and Zander found 965·3 water, 34·7 solid matter, 9·6 pancreatic and intestinal ferments, together with insoluble salts, 16·6 biliary matters (cholic, taurocholic, and glycocholate of sodium), 6·3 taurine, 0·7 fat, 3·7 extractive matter, 0·15 potassium, 1·45 sodium, 2·11 chlorine, 0·03 phosphoric anhydride, 0·06 earthy phosphates. In the intestinal juice from the upper part of the colon of a man, Busch found from 3·8 to 7·4 per cent.; Frerichs, from 2·2 to 5·6 per cent. solid matter.

The intestinal juice converts starch very quickly into sugar, and digests albuminous substances, flesh, &c., though much more slowly than the gastric juice. (Handwörterbuch d. Chem. 2te Aufl. ii. [3] 373.)

INULIN. $C^6H^{10}O^5$. *Helenin, Alantin, Menyanthin, Dahlin, Synantherin, Sinistrin.*—A substance isomeric with, and similar in its properties to, starch, discovered by Valentin Rose in 1804. It appears to be a very widely distributed constituent of plants, and is found especially in the roots of elecampane (*Inula Helenium*), dandelion (*Taraxacum dens leonis*), chicory (*Cichorium Intybus*), feverfew (*Pyrethrum Parthenium*), and meadow saffron (*Colchicum autumnale*); in the tubers of the potato, the dahlia, and the Jerusalem artichoke (*Helianthus tuberosus*), in Lerp-manna (from *Eucalyptus dumosa*), and probably in the seeds of the sun-flower (*Helianthus annuus*), and in certain lichens, viz. *Lichen fraxineus* and *Lichen fastigiatus.*

Preparation.—a. From Elecampane-roots.—The roots are boiled with a large quantity of water, the decoction is evaporated, the extract exhausted with cold water, and the inulin which remains undissolved is washed (Gaultier, Stratingh).—Or the roots are exhausted with hot water in a percolating apparatus; the concentrated effusion is evaporated to 10° or 12° Bm. and mixed with 2 pts. alcohol; and the inulin thereby precipitated is purified by reprecipitation with alcohol from its concentrated solution, and decolorised with animal charcoal (Thibault).—The helenin mixed with inulin prepared from elecampane-roots is extracted by boiling with alcohol. (Croockwit.)

b. From Potatoes or Dahlia-tubers.—1. The pulverulent deposit which separates in the cold from the expressed juice of potatoes is dissolved in hot water, and the solution is filtered, evaporated, and left to cool, whereupon it deposits inulin (Braconnot). —2. The nearly transparent juice expressed from dahlia-tubers is left to stand for some hours, whereupon it solidifies, from separation of inulin, to a stiff paste, which is to be washed and dried (Ludwig, N. Br. Arch. 32, 163).—3. Dahlia-tubers rubbed to a pulp are washed on a hair-sieve in a thin stream of water, as long as the liquid continues to run through milky, and the inulin which separates from it on standing is collected; or in case it is slow in settling down, the turbid liquid is heated till it boils, the coagulated vegetable albumin is skimmed off, and the remaining liquid is left to cool; it then, after a few days, deposits a thick pulp easy to wash (Liebig, Ann.

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Pharm. 2, 235).—4. Dahlia-tubers rubbed to a pulp are washed with cold water on a linen or woollen cloth; the residue is boiled for half-an-hour with 2 pts. water and a small quantity of chalk; the liquid is expressed; the extract, after being decolorised with animal charcoal and clarified with albumin, is evaporated till a film forms on it; and the inulin which separates on cooling is washed with cold water, and purified by solution in hot water and cooling. (Payen.)

Parnell uses peeled and washed dahlia-tubers, boils them for an hour and a half with 5 pts. of water, and purifies the inulin which separates from the evaporated extract by precipitating its aqueous solution with alcohol. Croockwit purifies the inulin thus obtained by boiling it with alcohol.

c. From Dandelion-roots. Obtained in the same way as from dahlia-tubers. (Wittstein, Repert. 71, 362; Herberger, Repert. 52, 399).

d. From Chicory-roots. The aqueous decoction is precipitated by neutral acetate of lead; the filtrate freed from lead is evaporated till a film forms on the surface; and the inulin which separates from it is purified by precipitating its aqueous solution with alcohol. (Woskresensky.)

e. From Lerp-manna. The substance is exhausted with boiling alcohol; the residue, consisting of starch, cellulose and inulin, is well boiled with water, and the inulin, which separates from the filtered extract on cooling, is collected and washed till the wash-water no longer exhibits the reactions of starch. (Anderson.)

Properties.—Inulin is a soft, white, tasteless, inodorous powder, resembling starch. When dried on glass or porcelain, it forms a translucent, brittle, dazzling white mass, which swells up in water. Specific gravity = 1·356 (Payen), 1·462 (Dubrunfaut). It is very hygroscopic, and sticks to the teeth and to moist paper. It exhibits lævo-rotatory power = 34° 42′. (Dubrunfaut, Compt. rend. xlii. 803.)

Most of the analyses which have been made of inulin agree nearly with the formula $C^6H^{10}O^5$. Woskresensky, however (J. pr. Chem. xxxvii. 309) obtained quantities of carbon and hydrogen much too large for this formula: he accordingly represents inulin by the formula $C^{24}H^{18}O^{14}$ (or $C^{24}H^{20}O^{14}$), and supposes that the inulin analysed by other chemists must have undergone partial oxidation; but the near accordance of most of these analyses renders this view improbable.

	Calculation.		Payen, at 150°. *a.*	Payen, at 170°. *b.*	Mulder, at 120°. *c.*	Mulder, at 120°. *d.*	Parnell, air-dried. *e.*
6 C	72	44·44	44·55	44·19	44·13	43·8	43·37
10 H	10	6·17	6·12	6·17	6·19	6·2	6·40
5 O	80	49·39	49·33	49·64	49·68	50·0	50·23
$C^6H^{10}O^5$	162	100·00	100·00	100·00	100·00	100·0	100·00

	Croockwit, at 120°—160°. *f.*	*g.*	Woskresensky, at 100°—120°. *h.*	*i.*	Anderson, at 150°. *k.*	Dubrunfaut, at 100°. *l.*
C	43·37	43·48	52·18	49·59	44·03	44·32
H	6·23	6·25	6·86	6·86	6·30	6·19
O	50·49	50·27	40·96	43·55	49·67	49·49
	100·00	100·00	100·00	100·00	100.00	100·00

a, *b*, from Iceland moss; *c*, from dandelion-root; *d*, from elecampane-root; *e*, *f*, *g*, from dahlia-tubers; *h*, from chicory-roots; *i*, from dandelion-roots (partially oxidised); *k*, from lerp-manna.

Inulin, immersed in cold water, or exposed to moist air, absorbs water, and crumbles to a dull-looking powder, consisting of *hydrated inulin*, $C^{12}H^{20}O^{10}.3H^2O$.

Inulin dissolves very sparingly in cold *water*, freely in boiling water, but the solution does not form a jelly like that of starch; it is insoluble in *alcohol*, which also precipitates it from its aqueous solution. It dissolves with brown colour in strong *sulphuric acid*, and is precipitated therefrom by ammonia, but not by water or alcohol. It is insoluble in *hydrochloric acid*, and in cold glacial *acetic acid*, but dissolves in the latter when warmed. The aqueous solution is not precipitated by *chlorine-water*, but forms a white precipitate with *infusion of galls*.

Inulin absorbs 3 per cent. *ammonia*, and dissolves in cold aqueous *potash*, forming a solution which leaves on evaporation a nearly colourless gum, and when mixed with acids, deposits, after a while, unaltered inulin.

Inulin dissolves in aqueous *cuprammonia* (an ammoniacal solution of cupric oxide), without previous tumefaction (Cramer, J. pr. Chem. lxxiii. 16), the solution yielding after a few hours, a copious blue amorphous precipitate, insoluble in water and in ammonia, soluble in tartaric and nitric acids (Schlossberger, J. pr. Chem. lxxiii. 373). It dissolves gradually in aqueous *nickel-ammonia*. (Schlossberger.)

The aqueous solution of inulin forms a white precipitate with *baryta-water*, and with chloride of barium mixed with potash.

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It does not precipitate aqueous *acetate of lead*, either neutral or basic, but with a solution of the neutral acetate containing ammonia, it forms a white precipitate containing quantities of lead-oxide varying in amount from 51·23 to 62·43 per cent. It is not precipitated by *ferrous, ferric*, or *cupric sulphate, mercuric nitrate, nitrate of silver*, or *chloride of gold*.

Decompositions.—1. Inulin heated above 100° melts, with colouring and loss of weight, and is converted into a pitchy, sweetish substance, very soluble in water (Braconnot), insoluble in water and in alcohol (Payen). By dry distillation it yields acetic acid, having a brown colour, but free from oily matter. When thrown on glowing coals, it emits the odour of burnt sugar.—2. Heated with *water* to 100°, it is slowly but completely converted into non-crystallisable, lævo-rotatory, fermentable sugar.—3. By boiling with *nitric acid*, inulin is converted into malic, oxalic, and acetic acids, but not into mucic acid. Its solution in fuming nitric acid is not precipitated by water.—4. When heated with strong *sulphuric acid*, it turns yellow, then brown, and is ultimately carbonised.—5. By *dilute acids*, either hot or cold, inulin is converted into sugar, without evolution or absorption of gas.—6. Aqueous *arsenic acid* dissolves inulin, with aid of heat; after continued action, the cooled solution no longer deposits inulin, but leaves, on evaporation, a rose-coloured mass, which afterwards becomes darker, and finally black, grape-sugar being first formed, afterwards formic and ulmic acids.—7. *Oxide of lead* converts inulin wholly or partially into glucic acid, which, if afterwards exposed to the air, is changed into apoglucic acid. A warm aqueous solution of inulin reduces other salts of lead, also those of copper and silver. When an ammoniacal solution of acetate of lead is precipitated by aqueous inulin, the filtrate separated from the white precipitate deposits spangles of lead after a few hours, and contains formic acid.—8. Inulin is not *fermentable*. Neither its rotatory power nor any of its other properties is altered by *diastase*.—9. It is digested in the stomach, and does not pass, as inulin, either into the urine or into the fæces.

Inulin is distinguished from starch by its reaction with *iodine*, which imparts to it only a fugitive brown colour; by its solubility in aqueous cuprammonia, by its power of reducing certain metals from their solutions; and by its inalterability under the influence of ferments.

IODACETIC ACID. $C^2H^3IO^2 = \left.\begin{matrix}C^2H^2IO\\H\end{matrix}\right\}O$. (Perkin and Duppa, Phil. Mag. [4] xviii. 54.)—This acid is obtained, as an ethyl-compound, by the action of iodide of potassium on bromacetate of ethyl diluted with three measures of alcohol, the mixture being digested at 40° in the dark for about two hours, and the iodacetic ether then distilled off. To obtain the free acid, the ether is converted into a barium-salt by digestion with hydrate of barium; this salt is decomposed by cautious addition of sulphuric acid; and the filtrate is crystallised in a vacuum.

Iodacetic acid forms thin, tough, colourless, rhombohedral plates, having a very sour taste, and not deliquescent. It melts at 82°, with slight decomposition, and solidifies again at 85°. It is decomposed, like bromacetic acid, by moist oxide of silver, with formation of glycollic acid:

$$C^2H^3IO^2 + AgHO = AgI + C^2H^4O^3.$$

Iodacetate of Ammonium is very soluble, crystalline, and non-deliquescent. The *potassium*-salt exhibits similar properties. The *barium*-salt, $C^2H^2IBaO^2$, is crystalline, moderately soluble in water, and precipitated by alcohol. The *lead-salt* crystallises in prisms, but easily splits up in solution into iodide of lead and glycollic acid:

$$C^2H^3IPbO^2 + H^2O = PbI + C^2H^4O^3.$$

Iodacetate of Ethyl is an oily liquid, heavier than water, and having a very irritating odour. *Iodacetate of Amyl* is oily, heavier than water, has the odour of pears, and gives off an irritating vapour.

Di-iodacetic Acid. $C^2H^2I^2O^2$. (Perkin and Duppa, Chem. Soc. Qu. J. xiii. 1.)—The ethyl-compound of this acid, obtained by acting on dibromacetate of ethyl with iodide of potassium, is converted into a calcium-salt by means of milk of lime; the calcium-salt is decomposed by hydrochloric acid, avoiding an excess; and the solution is left to crystallise. The acid is thus obtained as a beautifully crystalline sulphur-yellow compound, volatile at ordinary temperatures, and slightly soluble in water. It has a faintly acid taste, with metallic after-taste. It does not blister the skin.

The *di-iodacetates* are slightly yellow, crystalline, and permanent, excepting the potassium and sodium-salts, which are deliquescent. The *barium*-salt, $C^2HI^2BaO^2$, forms rhombohedral crystals, which give off iodine when heated. The *calcium*-salt forms yellow silky needles, also decomposed by heat. The *lead*-salt, $C^2HI^2PbO^2$, is

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obtained as a crystalline precipitate by adding a solution of the sodium-salt to acetate of lead, both being largely diluted. The *silver*-salt, prepared in like manner, forms a yellow crystalline powder, which, when gently heated, decomposes with slight explosion and evolution of iodine.

Di-iodacetate of Ethyl, $C^2H(C^2H^5)I^2O^2$, is a yellowish liquid, having a pungent, burning taste, and extremely irritating odour. It is insoluble. or nearly so, in water. Ammonia rapidly converts it into di-iodacetamide, $N.H^2.C^2HI^2O$, which is a pale yellow substance, sparingly soluble in water.

IODACETYL. C^2H^2IO.—The radicle of iodacetic acid.

IODAL. $C^2HI^3O = C^2I^3O.H$. *Hydride of Tri-iodacetyl* (i. 34).—This compound is said to be obtained by adding iodine to a mixture of alcohol and nitric acid. The iodine rapidly disappears, and an oil separates which may be purified by agitation with water and distillation over chloride of calcium. It begins to boil at 25°, but the boiling point gradually rises to 115°. Potash converts it into iodoform (Aimé, Ann. Ch. Phys. [2] lxiv. 217). Johnston (Phil. Mag. [3] ii. 215) obtained, by a similar process, an oily liquid which boiled at 110°, but decomposed and turned brown at the same time. Johnston regarded the product as iodate of ethyl (see Gmelin's Handbook, ix. 186). Schoonbroodt (Bull. Soc. Chim. de Paris, 1861, p. 109), by adding hypochlorite of potassium to an alcoholic solution of iodine till the latter was decolorised, obtained a copious precipitate consisting of small shining needles, easily soluble in water, sparingly in alcohol, and resolved by potash-ley into formic acid and iodoform: hence it was probably iodal.

IODAMIDES and **IODAMMONIUMS.** Under these terms may be included a number of compounds, mostly of an explosive character, produced by the action of iodine on ammonia. The composition and properties of these products vary according to the mode of preparation adopted.

I. **Iodamides.** By digesting iodine in excess of aqueous ammonia; by adding a large excess of aqueous or alcoholic ammonia to a saturated solution of iodine in alcohol, and then diluting with water; by adding ammonia to a solution of iodine in nitro-muriatic acid (which contains protochloride of iodine, ICl); or by decomposing the explosive compound called chloride of nitrogen, with iodide of potassium—a black powder is precipitated which when dry is violently explosive. It must be collected on a filter, and washed with water; and to guard against accidents in drying, it is advisable to divide the filter, with the moist precipitate upon it, into small pieces, and expose them to warm dry air at considerable distances from each other. Or the precipitate may be dried under a receiver filled with ammonia gas, in which case, according to Millon, there is no fear of explosion.

The product obtained by either of these processes, commonly called iodide of nitrogen, is a brownish-black soft powder, which when dry explodes from the slightest cause, producing a loud report and destroying any solid bodies that may be near it. The explosion is attended with a faint flash of violet light, nitrogen being set free as gas, and iodine in the form of very fine powder. It may be exploded by friction, even under water, and in the dry state can scarcely be touched without exploding, the slightest elevation of temperature, and even the friction produced by sliding over the surface of smooth paper, being sufficient to explode it. When moist, it decomposes slowly in contact with the air, yielding nitrogen, iodic acid, and hydriodic acid. A similar decomposition is produced more rapidly by boiling *water*, or by *alkaline solutions*. *Sulphydric acid* decomposes it, producing hydriodic acid, ammonia, and a deposit of sulphur. With *sulphurous acid*, it yields iodide of ammonium, hydriodic acid, and sulphuric acid. *Bromine-water* decomposes it instantaneously, *chlorine* more slowly: strong *nitric acid* attacks it violently. (Gladstone.)

This description applies to all the products obtained by the processes above-mentioned; nevertheless, these products are not absolutely identical in composition; but they all appear to be iodamides—that is to say, ammonia-molecules having the hydrogen more or less replaced by iodine—combined in some instances with ammonia itself. Gay-Lussac regarded the product of the action of iodine on ammonia as a compound of iodine and nitrogen alone, in fact, as tri-iodamide, NI^3, and, according to recent analyses by Stahlschmidt (see p. 281), this compound does appear to be formed under certain conditions; but repeated experiments by several chemists have shown that the explosive compound thus produced frequently also contains hydrogen: for when small portions of it in a state of perfect dryness are repeatedly exploded under a bell-jar, iodide of ammonium is deposited on the sides of the vessel.

According to Millon (Ann. Ch. Phys. [2] lxix. 78), the compound is mono-iodamide, NH^2I, and the decomposition just mentioned takes place as represented by the equation:

$$2NH^2I = NH^4I + I + N.$$

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Bineau (*ibid.* [3] xv. 71), by determining the quantities of hydriodic acid, ammonia, and nitrogen produced in its decomposition by sulphydric acid, was led to adopt the formula, NHI^2, which is that of di-iodamide:

$$NHI^2 + 2H^2S = NH^4I + HI + S^2.$$

Gladstone (Chem. Soc. Qu. J. iv. 34) takes the same view of its constitution. By decomposing with sulphydric acid, the compound produced by the action of ammonia on an alcoholic solution of iodine, he finds that it contains 2 at. iodine to 1 at. nitrogen, while its decomposition by aqueous sulphurous acid is represented by the equation:

$$NHI^2 + 2SH^2O^2 + 2H^2O = NH^4I + HI + 2SH^2O^4.$$

He also finds that the formula NHI^2 is in accordance with the formation of the compound by the action of hypochlorite of calcium or iodide of ammonium (observed by Playfair), that reaction being attended with evolution of ammonia, according to the equation:

$$CaCl^2O^2 + 2NH^4I = NHI^2 + CaCl^2 + 2H^2O + NH^3.$$

Bunsen (Ann. Ch. Pharm. lxxxiv. 1) has also examined the constitution of iodide of nitrogen, and arrived at different conclusions. He observes that the mode of formation of the explosive compound from iodine and ammonia, with hydriodic acid as the only secondary product, shows that it must be a substitution-product of ammonia, of the form NI^3, NHI^2 or NH^2I, associated at most with ammonia and hydriodic acid; 2. That it cannot contain hydriodic acid, because it dissolves in hydrochloric acid without evolution of gas, and forms a solution containing ammonia and protochloride of iodine, but no hydriodic acid; 3. That, to determine its composition, it is sufficient to ascertain how much ICl and how much NH^3 it yields with hydrochloric acid, and to see which of the following equations agrees with the results:

$$\begin{aligned}
NI^3 + 3HCl &= 3ICl + NH^3 \quad . \quad . \quad . \quad . \quad (a)\\
NHI^2 + 2HCl &= 2ICl + NH^3 \quad . \quad . \quad . \quad . \quad (b)\\
NH^2I + HCl &= ICl + NH^3 \quad . \quad . \quad . \quad . \quad (c)\\
NH^2I + NH^3 + HCl &= ICl + 2NH^3 \quad . \quad . \quad . \quad . \quad (d).
\end{aligned}$$

Preparations obtained by mixing cold and more or less saturated anhydrous alcoholic solutions of iodine and ammonia, which were not decomposed by washing with absolute alcohol, gave, when dissolved in hydrochloric acid, quantities of ammonia, iodine, and chlorine, in the atomic proportion of 2 : 3 : 3, showing that the constitution of the compound thus formed was $NI^3.NH^3$. A preparation obtained by adding ammonia to a solution of iodine in nitro-muriatic acid diluted with water, and washed as quickly as possible with cold water, gave, with hydrochloric acid, quantities of ammonia and protochloride of iodine in the atomic proportion of 5 : 12, showing that its formula was $4NI^3.NH^3$. When washed with water for any length of time, even till the greater part of the compound was decomposed, with separation of iodine and nitrogen, the undecomposed portion still yielded more than 1 at. ammonia to 3 at. chloride of iodine, a proof that ammonia entered essentially into its constitution. Bunsen is of opinion that there exist two distinct compounds, $NI^3.NH^3$ and $4NI^3.NH^3$, formed in the manner shown by the equations,

$$\begin{aligned}
2NH^3 + 6I &= NI^3.NH^3 + 3HI\\
8(NI^3.NH^3) + 3H^2O &= 2(4NI^3.NH^3) + 3(NH^4)^2O.
\end{aligned}$$

The formation of the so-called iodide of nitrogen by the action of ammonia on a solution of iodine in nitro-muriatic acid, would be inconsistent with this view, if that solution contained, not ICl, but, as is sometimes supposed, ICl^3, because NI^3 could not be formed from the latter. Bunsen has, however, shown that the solution of iodine in nitro-muriatic acid contains only ICl. The formation of the explosive compound from ICl is explained by the equation,

$$2NH^3 + 3ICl = (NI^3.NH^3) + 3HCl.$$

The immediate products of its explosion are nitrogen and hydriodic acid:

$$NI^3.NH^3 = N^2 + 3HI.$$

which latter is, for the most part, resolved by the high temperature into iodine and hydrogen, while another portion unites with the ammonia of the compound, forming iodide of ammonium, thereby setting free quantities of iodine and nitrogen equivalent to this ammonia.

The compound obtained by Bineau and by Gladstone, *viz.* di-iodamide NHI^2, is intermediate between the two compounds obtained by Bunsen:

$$2N^2I^3H^3 + N^2I^{12}H^3 = 9NHI^2$$

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Bunsen's first compound $NI^3.NH^3$, may be represented as tri-iodammonammonium, $N\left\{\begin{matrix}H^2\\NHI^2\end{matrix}\right.$, and the second compound $4NI^3.NH^3$, might be formulated in a similar manner.

Lastly, it appears from the experiments of Stahlschmidt (Pogg. Ann. cxix. 421; Bull. Soc. Chim. de Paris 1864, p. 149), that di- or tri-iodamide may be produced according as alcoholic or aqueous ammonia is added to an alcoholic solution of iodine. By mixing alcoholic solutions of ammonia and iodine, he obtained a compound yielding by analysis quantities of iodine and nitrogen in the proportion of 2 at. I to 1 at. N, therefore NHI^2.

On the other hand, a product obtained by adding aqueous ammonia to an alcoholic tincture of iodine, yielded by decomposition with *sulphydric acid*, products containing 3 at. I to 1 at. N, according to the equation,

$$NI^3 + 3H^2S = NH^4I + 2HI + S^2.$$

The same substance treated with *iodide of methyl*, yielded in 24 hours, two layers of liquid, the upper consisting of aqueous hydriodic acid and iodide of ammonium, while the lower contained iodoform and penta-iodide of tetramethyl-ammonium:

$$2NI^3 + 3CH^3I = 2NH^3 + \underset{\text{Iodoform.}}{3CHI^3},$$

$$\text{and } 2NI^3 + 9CH^3I = 2HI + \underset{\text{Iodoform.}}{CHI^3} + \underset{\text{Penta-iodide of tetramethyl-ammonium.}}{2N(CH^3)^4I^5}.$$

On treating the lower liquid with boiling absolute alcohol, a solution was obtained which deposited the penta-iodide in shining green crystals, while iodoform remained in the mother-liquor; and this mother-liquor being treated with potash, gave off ammonia and yielded iodoform, together with yellow crystals having the composition of di-iodomethylamide $N\left\{\begin{matrix}I^2\\CH^3\end{matrix}\right.$. The saline residue contained butyrate of potassium and other salts.

If the tri-iodamide used in the preceding reaction still retains ammonia, the products obtained are penta-iodide of tetramethylammonium, and a compound of 2 at. iodoform with mono-iodide of tetramethylammonium, $C^6H^{14}NI^7 = (CH^3)^4NI + 2CHI^3$.

By acting with ammonia on penta-iodide of tetramethylammonium (which contains 4 at. iodine in a state of less intimate combination than the fifth, and ready to act like free iodine), Stahlschmidt has obtained a compound containing $C^4H^{13}N^2I^5$, which may be regarded as a compound of di-iodamide, NHI^2, with tri-iodide of tetramethyl-ammonium. The same compound is formed on mixing alcoholic tincture of iodine with an ammoniacal solution of mono-iodide of tetramethyl-ammonium. It is a black powder, which explodes at 100°, or in contact with sulphuric acid, giving off nitrogen, and leaving the penta-iodide. The same decomposition takes place on heating its alcoholic solution. Sulphydric acid reduces it to mono-iodide of tetramethylammonium. Nitric acid decomposes it slowly. Heated with potash, it yields iodoform. It is insoluble in most liquids, but dissolves slightly in absolute alcohol. (Stahlschmidt.)

II. **Iodammonium.** NH^3I; or *Iodide of Ammonia*, $NH^3.I$. — Dry iodine absorbs dry ammonia-gas, 100 parts of iodine taking up 8·3 pts. of ammonia at + 10°, 9 pts. at 0°, and 9·4 pts. at −18°. The product is a blackish-brown very tenacious liquid, having a metallic aspect, smelling of ammonia and iodine, and imparting a brown stain to the skin and to paper. When heated, it gives off a portion of the ammonia and sublimes in violets vapours. Its lustre and tenacity are destroyed by excess of ammonia. It dissolves readily in alcohol, and is resolved by water into iodide of ammonium and di-iodamide:

$$2NH^3I = NH^4I + NH^2I.$$

In a current of hydrochloric acid gas, it is completely decomposed, yielding nitrogen gas, sal-ammoniac, iodide of ammonium, and free iodine. (Millon, Ann. Ch. Phys. lxix. 78.)

According to Bineau, 100 pts. iodine absorb 20·55 pts. ammonia-gas, yielding a product having the composition $N^3H^9I^2$. This may be represented as an *iodide of iod-ammon-ammon-ammonium* $\left[N\left\{\begin{matrix}H^3\\N\left\{\begin{matrix}H^2\\NH^3I\end{matrix}\right.\end{matrix}\right.\right].I$.

Millon's compound, if its composition has been correctly determined, is remarkable as presenting the only known instance of an ammonium-molecule existing in the free state.

III. **Iodide of Iodammonium.** $NH^3I^2 = (NH^3I).I$. —This compound, discovered

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by Guthrie (Chem. Soc. J. xvi. 239), is obtained: 1. By adding finely-powdered iodine to a saturated solution of nitrate or carbonate of ammonia mixed with about one-third of an equivalent quantity of potash. The iodine immediately liquefies, without perceptible rise of temperature, and unites with the elements of the ammonia, forming a very mobile brownish-black liquid, while the supernatant solution remains colourless. The iodide of iodammonium is separated by a pipette from the saline solution.—2. A similar, and probably identical liquid is obtained by adding to the solution of nitrate of ammonia, mixed with potash, a saturated solution of iodine in aqueous iodide of potassium.

Iodide of iodammonium dissolves in ether, alcohol, chloroform, sulphide of carbon, and aqueous iodide of potassium. When heated, it is partly resolved into iodine, and an iodiferous liquid, which may be distilled without decomposition, and is probably Millon's or Bineau's "iodide of ammonia."

$$NH^3I^2 = I + NH^3I.$$
$$3NH^3I^2 = I^4 + 3NH^3.I^2.$$

Exposed in the dry state to the air, it decomposes spontaneously into ammonia and iodine, no permanent gas being evolved. On agitating it in a eudiometer-tube with mercury, iodide of mercury is formed, and the mercury is depressed by the liberated ammonia, which latter is completely absorbed by water:

$$NH^3I^2 + Hg = NH^3 + HgI^2.$$

It is decomposed by water, colouring the water reddish-brown, from separation of iodine, evolving nitrogen gas, and yielding a residue of di-iodamide, which explodes spontaneously under water:

$$4NH^3I^2 + H^2O = 2NHI^2 + 2NH^4I + 2HI + H^2O = N^2 + 4HI + I^2 + 2NH^4I + H^2O$$

The formation of the di-iodamide is more rapid than its decomposition, so that some of it is left after the original compound is broken up.

The caustic *alkalis* effect the same decomposition as water, but more quickly, on account of the greater affinity of their metals for iodine.

Acids determine the formation of ammonia, *e. g.*:

$$NH^3I^2 + HCl = NH^4Cl + I^2.$$
$$NH^3I^2 + H^2SO^4 = (NH^4)^2SO^4 + I^2.$$

A portion of the compound prepared by the first method (p. 282) and decomposed in this way by dilute sulphuric acid, yielded in one experiment 5·92 per cent. NH^3 and 93·47 I, in another, 6·59 NH^3 to 63·04 I, the formula requiring 6·27 NH^3 to 93·73 I. On submitting the compound to fractional solution with chloroform, the residue was found to have exactly the same composition as the original substance, showing that the substance operated on was a definite compound, and not a mixture of two or more.

IODAMMONIUM. (See p. 282.)

IODANILINE. Syn. with Iodophenylamine. See Phenylamine.

IODANISIC ACID. $C^8H^7IO^3$. Produced, together with hydriodate of oxanisamic acid, by the action of hydriodic acid on diazoanis-oxanisamic acid:

$$\underset{\text{Diazoanis-oxanisamic acid.}}{C^8H^6N^2O^3.C^8H^9NO^3} + 2HI = \underset{\text{Hydriodate of oxanisamic acid.}}{C^8H^9NO^3.HI} + \underset{\text{Iodanisic acid.}}{C^8H^7IO^3} + N^2$$

It forms white needles, insoluble in water, easily soluble in alcohol and in ether. The *silver-salt* is a white amorphous precipitate. (P. Griess, Proc. Roy. Soc. x. 309; Jahresber. 1859, p. 466.)

IODARSENIOUS ACID. See Arsenic Oxyiodide of (i. 386).

IODATES. See Iodine, Oxygen-acids of.

IODAURATES. See Gold, Iodides of (ii. 929).

IODETHYLAMINE. See Ethylamine (ii. 538).

IODETHYLENE. See Ethylene, Iodated (ii. 579).

IODHYDRIC ACID. See Iodide of Hydrogen (p. 284).

IODHYDRINS. Compounds derived from glycerin or from glycide (ii. 896), by assumption of the elements of hydriodic acid and elimination of water. Only two have hitherto been obtained; both of which are glycidic ethers, viz.:—

Iodhydroglycide or Epi-iodhydrin . . $C^3H^5\{^{I}_{O}$ = $C^3H^6O^2 + HI - 2H^2O$.

Iodhydrodiglycide (Berthelot's Iodhydrin) $(C^3H^5)^2\{^{I}_{H}\{^{I}_{O^2}$ = $2C^3H^6O^2 + HI - 3H^2O$.

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The first has been already described (ii. 899). The second is obtained by saturating glycerin with hydriodic acid, keeping the liquid in a close vessel at 100° for forty hours, and then treating it with potash and ether. It is a syrupy liquid of a golden yellow colour, and specific gravity 1·783. It has a saccharine taste, dissolves about o·1 -third of its bulk of water, but is not itself soluble in water. It is soluble in alcohol, and still more in ether. It is not volatile without decomposition. It burns without residue, giving off vapours of iodine. Potash decomposes it slowly at 100°, producing iodide of potassium, a liquid which appears to be identical with glycerin, and a volatile liquid, probably oxide of glyceryl ($C^3H^5)^2O^3$. The iodine in cod-liver oil is perhaps in the form of this, or a similar compound. (Berthelot and De Luca, Compt. rend. xxxix. 748.)

IODIDE OF ACETYL. See ACETYL (i. 35).—The iodides of other organic radicles are also described under the several radicles.

IODIDE OF ALUMINIUM. See ALUMINIUM (i. 157).—The iodides of other metals are also described under the several metals.

IODIDE OF AMMONIA. See IODAMMONIUM (p. 282).

IODIDE OF AMMONIUM. See AMMONIUM-SALTS.

IODIDE OF BORON. See BORON (i. 627).

IODIDE OF HYDROGEN. IODHYDRIC OR HYDRIODIC ACID. HI. Iodine does not combine with hydrogen at ordinary temperatures, even under the influence of sunshine; but when hydrogen gas and iodine vapour are passed together through a red-hot tube, combination takes place. According to Blundell (Pogg. Ann. ii. 216), spongy platinum brings about the combination at ordinary temperatures. The affinity of iodine for hydrogen is inferior only to that of oxygen, fluorine, chlorine, and bromine; consequently iodine separates hydrogen from most of its combinations, *viz.* from phosphoretted hydrogen, sulphydric acid, ammonia, and many organic compounds, *e.g.* alcohol, ether, and volatile oils, the result being in all cases the formation of hydriodic acid (Gaultier; Colin). Iodine does not decompose *water*, even at a red heat, or at all events, produces mere traces of iodic and hydriodic acids (Gay-Lussac). If, however, there is likewise present any substance that can take up the oxygen of the water, hydriodic acid is produced in abundance. Hence water and iodine, in contact with *phosphorus*, form hydriodic acid and phosphorous acid (Gay-Lussac): with *sulphurous acid*, only however when a considerable quantity of water is present, they yield hydriodic and sulphuric acids. With *sulphites*, if largely diluted, the products are hydriodic acid and a sulphate; similarly with *hyposulphites;* with *arsenious acid*, hydriodic acid and arsenic acid; with *stannous salts*, hydriodic acid and a stannic salt; and with certain *metals*, hydriodic acid and a metallic oxide.

Preparation.—1. *In the gaseous state.*—*a.* 1 pt. of phosphorus and 9 pts. of iodine are moistened with a small quantity of water, or covered with moistened glass-powder, and heated in a retort connected with a mercurial trough. Towards the end of the operation, hydriodate of phosphamine (p. 201) may sublime. Personne (Compt. rend. lii. 468) recommends the use of amorphous phosphorus for this purpose. The phosphorus is to be introduced into a tubulated retort, covered with a layer of water, and iodine added by successive portions, while the whole is gently heated. A regular stream of hydriodic acid-gas is then given off quite free from iodine-vapour.—*b.* 1 pt. of phosphorus is gently heated with 14 pts. of iodide of potassium, 20 of iodine, and a small quantity of water. If the evolution of gas becomes too violent, the vessel must be plunged into cold water; if it becomes too slow, heat must be again applied (Millon, J. Pharm. xxviii. 299):

$$4KI + I^{10} + P^2 + 7H^2O = K^4P^2O^7 + 14HI.$$

2. *In the liquid state.*—Iodine and persulphide of hydrogen, which, when they come in contact, unite, and form a yellowish-brown liquid, are placed together at the closed end of a dry glass tube; and at a short distance from them, in a bend of the tube, is placed a small quantity of water. If the tube be then sealed, and the first-mentioned liquid brought in contact with the water, decomposition takes place, resulting in the separation of sulphur and hydriodic acid, a considerable portion of the latter condensing in the liquid state. (Kemp, Phil. Mag. [3] vii. 444.)

3. *In aqueous solution.*—The aqueous acid may be prepared by passing the gas obtained by either of the preceding methods into water, which absorbs it very rapidly and in large quantity; or directly: 1. By distilling iodine with phosphorus and a large quantity of water.—2. By passing sulphydric acid gas into water in which iodine is diffused, the liquid being well agitated all the while, till the iodine has disappeared, and the liquid, which was brown at first, has become colourless; the liquid is then filtered and heated to commencing ebullition, in order to expel the excess of sulphydric

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ur, as it precipitates, envelopes the iodine which
nd Dumas recommend the process of saturating
id from the undissolved portion—converting the
by means of sulphydric acid—digesting in this
dissolves much more abundantly in the hydriodic
in—once more saturating with sulphydric acid—

Another method is that of Stratingh, which
gas through a solution of iodine in 16 pts. of
of water, and freeing the product by distillation
acid. The acid prepared in this manner is liable,
of disagreeable odour, arising from the action of
. Iodide of barium dissolved in water is exactly
of sulphuric acid, and the product is separated
Glover, Phil. Mag. [3] xix. 92).—4. Granulated
till the liquid becomes colourless; sulphydric
the liquid decanted (Joss, J. pr. Chem. i. 133).
ined by either of these methods may be concen-

lourless gas, which reddens litmus strongly, and
. It has a very sour suffocating odour, extinguishes

Its specific gravity, according to Gay-Lussac's
s that the gas is composed of equal volumes of
hout condensation; for the density thence deduced

gen in unity, and 64 × 0·0693 = 4·4352 referred

d by pressure (p. 284). The liquid acid has a
orming a transparent colourless mass intersected

gas; its taste is pungent at first, afterwards
ated, it fumes strongly in the air. Its specific
s strength. An acid containing 57·0 per cent.
essure of 774 mm. A weaker or a stronger acid
distillation under the ordinary pressure (in an
omposition). When dry hydrogen gas is passed
the remaining acid attains a constant strength,
to 60·7 per cent. HI, if the experiment is made
, and from 58·2 to 58·5 per cent. HI, if it has
Chem. Soc. J. xiii. 160.)

ydriodic acid and oxygen gases passed through a
water and iodine (Gay-Lussac). The aqueous
ition when exposed to the air, becoming brown
wing compounds give up their oxygen to the
ning water and separating iodine. Hydrated
it into water (Thénard). *Sulphurous anhy-*
ater, sulphur, and iodine:

$$= 2H^2O + S + I^4.$$

e no action on one another (Dumas). Hydri-
ous solution, is decomposed by strong *sulphuric*
and free iodine:

$$= H^2O + H^2SO^3 + I^2.$$

d and hydriodic acids are reproduced. Aqueous
er and iodine:

$$HI = 3H^2O + I^6.$$

ic acid, both in the gaseous form and in the state
ric acid yields iodine, water, and nitric oxide
verted by hydriodic acid into ferrous salts, iodine
(Gay-Lussac).—3. *Chlorine gas*, in small
nto hydrochloric acid and iodine:

$$I = HCl + I;$$

cid and trichloride of iodine; *e.g.*

$$= HCl + ICl^3.$$

er, *bromine* and hydriodic acid gas yield hydro-

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bromic acid gas and iodine, the action being attended with evolution of heat (H
Hence hydriodic acid imparts a blue colour to starch on the addition of ch
bromine (not in excess), or of sulphuric, nitric, or iodic acid, or a mixture o
chloric acid and chlorate of potassium.—4. *Potassium, zinc, iron, mercury,* a
metals, immersed in this gas, are converted into iodides, 1 volume of hydrog
at the same time liberated from 2 volumes of hydriodic acid gas (Gay-Lu
5. With most *basic metallic oxides*, hydriodic acid forms water and a metalli
Some of these iodides separate immediately, so that, with the salts of certain
oxides, aqueous hydriodic acid forms precipitates consisting of metallic iodi
distinguished by the following colours: Oxide of bismuth, brown; oxide
orange-yellow; mercurous oxide, greenish-yellow; mercuric oxide, scarlet;
silver, yellowish-white. Other metallic iodides remain dissolved in the liquid
that state may be regarded as hydriodates of metallic oxides. With *metallic p*
e.g. the peroxide of manganese or of lead, hydriodic acid forms a metallic io
hydriodate), water, and free iodine; *e.g.*

$$PbO + 2HI = PbI^2 + H^2O + I.$$

With many *organic compounds*, hydriodic acid reacts in the same manner
inorganic compounds, sometimes deoxidising them, with formation of water a
nation of iodine, sometimes simply exchanging its hydrogen for a radicle of the
compound. Examples of the first mode of action are afforded by *mannite*, wit
hydriodic acid yields iodide of hexyl, water, and iodine (p. 154), and by *eryt*
nite, with which it yields in like manner iodide of tetryl (ii. 505). An instan
second mode of action is exhibited by *salicylate of methyl* (wintergreen oil), wi
hydriodic acid forms iodide of methyl and salicylic acid. (Lautemann, *A*
Pharm. cxxv. 13.)

$$C^7H^5(CH^3)O^2 + HI = CH^3I + C^7H^6O^2.$$

It is by reactions of this kind that Matthiessen and Foster (Chem. Soc. J. x
have shown that cotarnine and its derivatives are methylised compounds
(Cotarnine, ii. 90; Hemipinic acid, iii. 142; Opianic acid, and Narcotine.)

Hydriodic acid unites directly with ammonia, phosphamine, and other
amines, phosphines, arsines, stibines, &c., forming salts, which may be regarde
as hydriodates of these ammonia-derivatives, or as iodides of the corresponding
tives of ammonium, *e.g.* hydriodate of triethylamine, $N(C^2H^5)^3.HI$, iodide of
ammonium, $[N(C^2H^5)^3H]I$. Similarly with other organic bases.

It likewise unites directly with many hydrocarbons containing even nu
hydrogen-atoms; the olefines and camphenes, for example. Greville Willi
distilling the hydrocarbons obtained from Boghead naphtha with fuming hydrio
obtained compounds which might be regarded as hydriodates of olefines, $C^nH^{2n}.$
iodides of the corresponding monatomic alcohol-radicles, $C^nH^{2n+1}I$, as whe
with alcoholic ammonia, they yielded the hydriodates of the corresponding
$C^nH^{2n+3}N.HI$. The hydriodates of the olefines are not, however, in all cases
with the corresponding monatomic alcoholic iodides; hydriodate of amylene
ample, is merely isomeric with iodide of amyl; for when treated with moist
silver, it yields a hydrate of amylene, not exhibiting the properties of commo
alcohol. Similarly with hydriodate of hexylene (p. 188).

IODIDE OF NITROGEN. See Iodamides (p. 280).

IODIDES, METALLIC. These compounds are obtained by the same
that yield the chlorides and bromides.

1. By the direct action of iodine on a metal, frequently even at ordinary temp
as in the case of mercury. The combination is attended with development
sometimes with flame, which is coloured violet by the iodine vapour (*e.g.* p
sodium).

2. By the action of iodine on certain metallic oxides, hydrates, or ca
Iodine displaces the oxides of potassium, sodium, barium, and calcium at a
and that of oxide of silver at ordinary temperatures. When solutions of ca
carbonated alkali are treated with iodine, mixtures of iodide and iodate are p
which last salt is decomposed by heat into iodide and oxygen. Iodine and
of barium, when mixed with water, decompose into iodide of barium and oxyg

$$I^2 + BaO^2 = BaI^2 + O^2.$$

3. By the action of certain metals, such as potassium, zinc, and iron, on hydrio
the metal then replacing the hydrogen.—4. By saturating hydriodic acid wit
hydrates, or carbonates. With a peroxide and hydriodic acid, iodine is libe
5. The insoluble iodides are prepared by adding hydriodic acid or the solut
metallic iodide to solutions of the heavy metals.

All iodides are destitute of metallic lustre; some of them are very be

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coloured. Their specific gravity is often lower than the mean specific gravity of their constituents: such is the case with the iodides of potassium, lead, copper, and silver. (Boullay.)

But few metallic iodides are decomposed by heat alone; the iodides of gold, silver, platinum, and palladium, however, give up their iodine when heated. Most metallic iodides when ignited in open vessels, so that the air has excess to them, give up their iodine, and are converted into oxides; such, however, is not the case with the iodides of potassium, sodium, bismuth, and lead. *Chlorine*, at red heat, decomposes the metallic iodides, converting them into chlorides, and either setting the iodine free or forming chloride of iodine. *Bromine* acts in a similar manner. Chlorine-water likewise liberates the iodine. *Hydrochloric acid* gas decomposes metallic iodides at a red heat, forming hydriodic acid gas and a metallic chloride. Concentrated *sulphuric* and *nitric acid* and likewise *acid sulphate* of *potassium* decompose all metallic iodides on the application of heat, the products being iodine, which escapes in violet vapours (which give a blue colour to paper moistened with starch), and a sulphate or nitrate of the corresponding metal. When this change is produced by nitric acid, pernitric oxide is formed at the same time; sulphuric acid and acid sulphate of potassium evolve sulphurous anhydride, sometimes also sulphydric acid. Sulphuric acid or acid sulphate of potassium with peroxide of manganese, peroxide of lead, or chromate of potassium, produces the same decomposition, but without evolution of sulphurous anhydride. A bead of microcosmic salt saturated with *oxide of copper* communicates a beautiful green colour to the blow-pipe flame on the addition of a metallic iodide (Berzelius). Metallic iodides agitated with sulphuric acid and *sulphide of carbon*, communicate an amethyst-red tint to the latter.

Very few metallic iodides remain unaltered in contact with *water:* such, however, is the case with the iodides of bismuth, lead, copper, and several of the noble metals. Some of them are converted by water into an oxide, which is precipitated, and hydriodic acid which dissolves in the water (iodide of tin): or into a precipitated compound of iodide and oxide of the metal, and a solution of the iodide in aqueous hydriodic acid (the iodides of antimony and tellurium). Most metallic iodides are perfectly soluble in water; and the solution may be regarded as containing either the unaltered iodide, or a hydriodate of the oxide formed by double decomposition (*e.g.* the iodides of the alkali-metals, iron, nickel, cobalt, &c.).

The soluble iodides are extremely poisonous. When evaporated out of contact of air, they generally leave anhydrous metallic iodides, which partly separate in the crystalline form before the water is wholly driven off. The earthy hydriodates, however, are resolved, on evaporation, into the earthy oxides and hydriodic acid, which escapes. A very small quantity of *chlorine* colours the solution yellow or brown, by partial decomposition; and a somewhat larger quantity takes up the whole of the metal, forming a chloride (or hydrochlorate), and separates the iodine, which then gives a blue colour with starch; a still larger quantity of chlorine gives the liquid a paler colour, and converts the separated iodine into trichloride of iodine, which does not give a blue colour with starch, and frequently enters into combination with the chloride produced. Strong *sulphuric acid* and somewhat concentrated *nitric acid* colour the solution yellow or brown; and if the quantity of the iodide is large, and the solution much concentrated or heated, they liberate iodine, which partly escapes in violet vapours. *Starch* mixed with the solution, even if it be very dilute, is turned blue—permanently, when the decomposition is effected by sulphuric acid; for a time only when it is effected by nitric acid, especially if that acid be added in large quantity. If the sulphuric acid contains sulphurous acid, which is very likely to be the case with fuming oil of vitriol, it does not produce the blue colour, even when added in large excess. If a liquid in which iodine is present (urine, for example) contains much organic matter, which may decompose the sulphuric acid and form sulphurous acid, it will not produce the blue colour with starch and sulphuric acid unless it be diluted with water (Dupasquier, J. Pharm. 28, 218). If the solution likewise contains a salt of *iodic acid*, most acids produce a brown colour and separate iodine; because, by virtue of their affinity for the base of the iodate, they facilitate the mutual decomposition of the hydriodic and iodic acid: $IHO^3 + 5HI = 3H^2O + 3I^2$. The separation of iodine, and the blueing of the starch likewise takes place on adding hydrochloric acid to the solution, together with a stannic, ferric, or cupric salt, or a salt of chromic acid. Also, if the solution of the iodide be covered with gelatinous starch, the negative pole of a small voltaic battery immersed in the former, and the positive pole in the latter, the starch is turned blue in the neighbourhood of the positive wire, even if the solution contains a much larger quantity of bromide or chloride than of iodide (Steinberg, J. pr. Chem. xxv. 288). If the aqueous solution of a metallic iodide contains only $\frac{1}{10,000}$ part of iodine, it gives a strong blue colour with dilute gelatinous starch, on the addition of aqua-regia: with $\frac{1}{100,000}$ part of iodine, the

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precipitate is violet; with $\frac{1}{500,000}$, rose-coloured; and with $\frac{1}{500,000}$, a pale rose-colour is produced after the lapse of a few hours (Harting, J. pr. Chem. xxii. 46). If the solution likewise contains a large quantity of metallic chloride, the blueing of the starch is not readily produced by the addition of nitric acid, in consequence of the formation of chloride of iodine: in this case, a solution of starch in boiling dilute sulphuric acid may be added to the solution of the iodide, and then a very small quantity of chlorine water, the liquid being stirred at the same time. (Berzelius.)

The aqueous solution of an iodide gives a brown precipitate with salts of *bismuth*; orange-yellow with *lead-salts*; dirty-white with *cuprous* salts, and also with *cupric* salts, especially on the addition of sulphurous acid; greenish-yellow with *mercurous* salts; scarlet with *mercuric* salts; yellowish-white with *silver*-salts; lemon-yellow with *gold*-salts; brown with *platinic* salts, first however turning the liquid dark brown-red; and black with salts of *palladium*, even when extremely dilute. All these precipitates consist of metallic iodides, many of them soluble in excess of the soluble iodide: the silver precipitate is insoluble in nitric acid and very little soluble in ammonia.

When iodine is added to an aqueous solution of a salt of hydriodic acid, the liquid takes up an additional quantity of iodine, equal, according to Baup (J. Pharm. ix. 46) to that which it already contains. It thereby acquires a dark-brown colour, and is supposed by some chemists to contain a *metallic polyiodide* or a salt of *hydriodous acid*; but the affinity by which the iodine is retained is very feeble.

Many metallic iodides absorb *ammonia* in definite proportions, forming compounds which may be regarded as iodides of ammonium-molecules, having part of the hydrogen replaced by a metal.

Some of these compounds unite with the *oxides* of the corresponding metals, forming **oxyiodides**, *e.g.* antimony and tellurium.

Metallic iodides also unite with one another, forming **double iodides** or **iodine-salts**.

IODIDES, ORGANIC. 1. *Acid.*—The iodides of acid organic radicles have not been much studied. Iodide of acetyl, C^2H^3OI, is obtained by the action of iodide of phosphorus on acetate of potassium or acetic anhydride; and iodide of benzoyl, C^7H^5OI, by the action of iodide of potassium on chloride of benzoyl. These acid iodides resemble the corresponding chlorides, but are much more easily decomposible.

2. *Alcoholic Iodides, Iodhydric* or *Hydriodic ethers.*— The monatomic alcoholic iodides are produced by the action of hydriodic acid, or iodide of phosphorus, on the corresponding alcohols, and by that of hydriodic acid on the corresponding diatomic hydrocarbons, *e.g.* iodide of amyl, $C^5H^{11}I$, from amylene, C^5H^{10}, and hydriodic acid. It is doubtful, however, whether the iodides obtained by this last process are really identical, or only isomeric with those obtained from the alcohols (p. 286).

The monatomic alcoholic iodides are less stable than corresponding chlorides, sometime decomposing under the influence of *light*, into the alcohol-radicle and free iodine, *e.g.* iodide of ethyl.

Heated in sealed tubes with certain metals, viz. *zinc*, *potassium*, or *sodium*, they yield a metallic iodide and the alcohol-radicle: *e.g.* zinc with iodide of ethyl; potassium or sodium with iodide of tetryl. With *mercury*, *tin*, *lead*, *arsenic*, *antimony*, and a few other metals, under the influence of heat, or of the sun's rays, they yield the iodides of organo-metallic bodies; thus, iodide of ethyl, enclosed in a sealed tube with stripe of tinfoil, and heated in a sealed tube to 180°, or exposed to the sun's rays concentrated by a lens or mirror, yields iodide of stannethyl, $(C^2H^5)^2SnI^2$ (ii. 235). Sometimes the organo-metallic compound thus formed acts further on the iodide, giving rise to new products (ii. 533, 535). Similar reactions take place when the alcoholic iodides are heated with the arsenides, antimonides, stannides, &c. of potassium or sodium, the organo-metallic radicles being then formed with greater facility, because the alkali-metal unites with the iodine.

The alcoholic iodides, heated in sealed tubes with *ammonia*, yield a mixture of the iodides of various ammonium-bases, in which the hydrogen of the ammonium is more or less replaced by the alcohol-radicle; thus, iodide of methyl with ammonia yields a mixture of the iodides of ammonium, and of methyl-, dimethyl-, trimethyl-, and tetramethyl-ammonium. With *primary* and *secondary monamines*, they react in a similar manner, the reaction becoming less complex as the amine itself is of a higher order. With *tertiary monamines* they unite directly, yielding the iodides of ammonium-bases in which the hydrogen is wholly replaced by the alcohol-radicle, *e.g.*

$(C^2H^5)^3N$	+	C^2H^5I	=	$(C^2H^5)^4NI$
Triethyl-amine.		Iodide of ethyl.		Iodide of tetrethyl-ammonium.

Similarly with tertiary *phosphines*, *arsines*, *stibines*, &c.

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ssium- or *sodium-alcohols* yield the oxides of

$$= \quad NaI + (C^2H^5)^2O$$
Ethylic oxide.

$$= \quad NaI + CH^3.C^2H^5.O$$
Methyl-ethylic oxide.

ey yield compound ethers, *e.g.*:

$$= \quad AgI + \left.\begin{matrix} C^2H^3O \\ C^2H^5 \end{matrix}\right\} O$$
Acetate of ethyl.

iodides are decomposed by these several reagents to the preparation of other compounds of the

lides of the olefines, $C^nH^{2n+2}I^2$, which are the produced by direct combination; also by passing onatomic alcoholic iodides through a red-hot

$C^2H^4I^2 + C^2H^4 + H^2$;

on the diatomic alcohols (ii. 578). The few ine solids, easily resolved into iodine and the ition taking place slowly, even at ordinary tem- mposed by *alcoholic potash*, yielding iodated $C^2H^4I^2$, is resolved into hydriodic acid, HI, and ith *ammonia* have not been much examined, but the corresponding bromides. (See ETHYLENE-

es resemble the corresponding bromides and ner above described by the action of metals and e influence of heat or light.

ee IODAMIDES (p. 208).

SELENIUM, SULPHUR, and **TELLU**

ymbol, I.—This element was discovered in 1812, ner-liquor of kelp from which carbonate of soda roperties were examined by Clement and 4), and afterwards more completely by Davy ussac (Ann. Chim. lxxxviii. 311, 319; xci. 5). ord ἰόν (violet), on account of the colour of its

and other mineral waters; also in sea-water, roportion of iodine in sea-water is, however, so by operating upon very large quantities; but it arine plants and animals, especially in certain . These plants are collected on the coast of burnt to ashes in a shallow pit to form kelp or valued chiefly for the carbonate of sodium that ore economically manufactured from chloride of chloride of potassium and the iodine obtained xists in kelp in the form of iodide of potassium ich more soluble than the other constituents, arbonates and chlorides have crystallised out. land-plants; *e.g.*, in tobacco, and in a species rdens on the fresh-water lakes near the city of

in iodine, viz., the common sponge, the horse- *Tubularia*, *Rhizostoma*, *Cyana*, *Doris*, *Venus*, and er oil, the pale oil containing, according to De own oil 0·0406, and the brown oil 0·0295 per cent. inerals, *viz.*, as iodide of mercury and iodide of or magnesium, in Chili saltpetre; as iodide of mites; in the rock-salt of Halle in the Tyrol, dium; and sublimes as iodide of ammonium, ning coal-mine of Commentry.

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Iodide of ammonium has been found in gas-water, in the coke left and in the ashes of coal and peat from various localities.

Chatin (Compt. rend. xxx. 352; xxxi. 280; xxxii. 669; xxxiii. 519 found iodine in the waters of various streams and rivers, in quantity i the proportion of iron present, and more abundantly in the waters o tricts than in those from the oolitic and limestone formations; also in of Paris, Pisa, Florence, and other localities; but none in the rain-w tainous districts. He also states that it is sometimes present in the localities; but Lohmeyer (Phil. Mag. [4] vi. 237), Macadam (Che vi. 166) and others have failed to detect its presence in the air. Maca iodine in commercial potash, in various samples of alkaline carbonates (us in the ashes of wood-charcoal, in coals, and in numerous plants.

Preparation.—I. From *varec* or *kelp*. The material is exhausted w the solution is freed as much as possible, by evaporation and cooling, tallised salts contained in it (chloride of potassium, chloride of sodium sodium, sulphate of sodium, &c.); and the mother-liquor—which, be sodium, still contains sulphide and hyposulphite of sodium, and a port already mentioned*—is subjected to one of the following processes: 1. a subliming apparatus with oil of vitriol:

$$2NaI + 2H^2SO^4 = Na^2SO^4 + 2H^2O + SO^2 + I^2$$

This method is not very advantageous, because the sulphurous acid evo the iodine and the water which is present, in such a manner as to pro and sulphuric acids. (Soubeiran.)

2. The mother-liquor is heated in a subliming apparatus with pe ganese and sulphuric acid (Wollaston):

$$2NaI + 2H^2SO^4 + MnO^2 = Na^2SO^4 + MnSO^4 + 2H^2O +$$

Mr. Whytelaw, of Glasgow, adds one measure of oil of vitriol, careful portions at a time, to eight measures of the mother-liquor contained in —whereupon, carbonic anhydride and sulphydric acid (from the sulphide first evolved; and, after exposure to the air for a day or two, sulphu (from the hyposulphite of sodium) escapes, and sulphur is precipita pours off the liquid from the crystallised sulphate of sodium into a placed horizontally in a sand-bath, and fitted with a head, the beak o into the first of three tubulated receivers luted one into the other; hea to 65° C. (149° F.); and, after adding the peroxide of manganese and head, gradually raises the temperature to 100°, but not higher, becau (244° F.) chloride of iodine begins to distil over. Sometimes also cy collects in the last receiver in white, needle-shaped crystals. The liquid in the retort still contains iodine, and on cooling, deposits crystals of iod double iodide of lead and sodium.

3. The mother-liquor is evaporated to dryness, the residue heated w manganese, and the iodine precipitated from the filtered solution by chl Barruel's method, which is carried out as follows:—The residue obta rating the mother-liquor to dryness is mixed with $\frac{1}{10}$ of its weight manganese, and the mixture heated in an iron vessel to commencing re all the while), but not high enough to cause the evolution of vapours heat is continued till a sample of the mixture treated with sulphuric evolves sulphydric acid or deposits sulphur; that is to say, till the sulphide and hyposulphite of sodium are converted into sulphate. Th dissolved in such a quantity of water that the solution may have a sponding to 36° of Baumé's hydrometer; chlorine gas is passed throu liquid, which is constantly stirred, till a sample treated with more chlo gives a precipitate of iodine (excess of chlorine would convert the iodin and redissolve it), and the pulverulent precipitate of iodine is collect and purified by sublimation. Mohr is of opinion that a loss of iodin this process during the heating of the evaporated residue with mangane

4. The mother-liquor is precipitated by a copper-salt and metallic cuprous iodide heated with peroxide of manganese (Soubeiran). Th is diluted with water, and mixed with a solution of sulphate of copper, precipitate is produced:

$$4NaI + 2CuSO^4 = 2Na^2SO^4 + Cu^2I^2 + I^2;$$

the liquid containing the free iodine is separated by decantation and

* A mother-liquor from *varec*, examined by Soubeiran, contained no carbonate or s cipal salts contained in it, in addition to the iodides, were the nitrates of calcium and

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the precipitated cuprous iodide, and mixed with sulphate of copper and iron filings till it no longer smells of iodine:

$$I^2 + 2CuSO^4 + Fe^2 = Cu^2I^2 + 2FeSO^4;$$

and the cuprous iodide thus produced is quickly separated by elutriation from the excess of iron-filings and from the liquid, before the ferrous sulphate has time to oxidate in the air. The two portions of iodide, obtained as above, are next dried at a gentle heat (a stronger heat would decompose the cuprous iodide, since it is mixed with basic ferric sulphate, and evolve iodine); the whole is mixed with twice or three times its weight of peroxide of manganese, and a sufficient quantity of sulphuric acid to form it into a paste; and the mixture is strongly heated in a subliming apparatus:

$$Cu^2I^2 + 2MnO^2 + 4SH^2O^4 = 2CuSO^4 + 2MnSO^4 + 2H^2O + I^2;$$

or the sulphuric acid is dispensed with, and a stronger heat applied:

$$Cu^2I^2 + 3MnO^2 = 2CuO + Mn^2O^4 + I^2.$$

In both cases, the iodine which passes over is accompanied by water derived from the hydrated cuprous iodide, from the sulphate of calcium precipitated with it, and from the sulphuric acid when it is used in the process. This water holds in solution a portion of the iodine, which may be again precipitated by sulphate of copper. By this process, 100 pts. of the mother-liquor yield 1 pt. of iodine.

II. *From the mother-liquor of the Caliche of Peru.*—This mother-liquor contains, according to Reichardt's analysis:

Nitrate of sodium	23·300
Chloride of sodium	8·594
Sulphate of magnesium	2·214
Chloride of magnesium	1·121
Iodate of sodium	0·440
Water, given off at 100°	57·406
Combined water (and loss)	6·925
	100·000

According to Grüneberg (J. pr. Chem. lx. 172), part of the iodine in this liquid is in the form of iodide of magnesium, which is decomposed, during the evaporation, into magnesia and hydriodic acid, thereby occasioning loss of iodine; this however may be prevented by the addition of caustic soda. The liquor is then treated with iron filings and sulphate of copper (as in Soubeiran's method) till the whole of the iodine is precipitated as ferrous and cuprous iodide:

$$\underset{\text{Iodate of sodium.}}{4NaIO^3} + 2CuSO^4 + Fe^{12} = Cu^2I^2 + FeI^2 + 2FeSO^4 + 10FeO + 2Na^2O;$$

and the precipitate, which also contains oxychloride of copper, is distilled with peroxide of manganese and sulphuric acid. The receiver contains crystals of iodine and chloride of iodine. The latter is heated with carbonate of potassium, which separates all the iodine, with formation of chloride and chlorate of potassium.

Jacquelin and Favre extract the iodine from the mother-liquors of caliche and commercial nitrate of sodium, by the following process, founded on the action of sulphurous acid on the iodates:

$$Mg(IO^3)^2 + 5H^2SO^3 = MgSO^4 + 4H^2SO^4 + H^2O + I^2.$$

The solution of the nitre having been concentrated to 36° or 37° Bm., a sample of it is mixed with aqueous sulphurous acid, cautiously and with constant stirring, until all the iodine is precipitated; the quantity of sulphurous acid used is then noted; and from the data thus obtained, the manufacturing operations are managed.

The solution of the nitre is run into a cistern built of stone or fire-bricks, and closed with a cover coated on the under side with glass plates. The cistern is fitted with an agitator, having stoneware arms worked from above through the cover, while the solution of sulphurous acid is being mixed with the liquid. The iodine which precipitates is collected, washed, and sublimed as above.

If the iodine is present in the form of iodide and iodate together, both chlorine and sulphurous acid must be employed, the necessary quantities having been previously ascertained by test-samples. If the iodate is present in the largest proportion, the chlorine-water is first used, and then the aqueous sulphurous acid; but when the iodate is the chief ingredient, the order of treatment is reversed.

III. *From Mineral waters.*—The quantity of iodine existing in certain mineral waters and in spent artificially iodised baths may be extracted by means of charcoal, which completely precipitates free iodine on the surface of its particles, where it

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remains fixed like a dye upon cloth, and cannot be removed by hea
or by water or alcohol either hot or cold. Animal charcoal acts most p
lamp-black is recommended for the purpose on account of its chea
state of fine division. The water containing the iodine-compound havin
with a mixture of 1 pt. sulphuric to 2 pts. nitric acid, to set the i
run on to a filter filled with charcoal, and the charcoal thus iodised is
another filter, where it is mixed with hydrated protoxide of iron, whereby
converted into soluble iodide of iron, which may be obtained in the solid
porating in a current of hydrogen, or distilled with peroxide of manganese
acid in the usual way, to obtain iodine.

Purification.—The iodine obtained by either of the preceding proc
purified by washing with a small quantity of water, pressing between
and subliming a second time. According to Serullas, the iodine of com
completely purified by solution in alcohol, filtration, and precipitation w

For further details relating to the manufacture of iodine, see *Richardso
Chemical Technology*, vol. i. part 3, pp. 562–575.

Properties.—Iodine is at ordinary temperatures a crystalline solid, hav
black colour and metallic lustre, like plumbago or specular iron-ore. It
only in very thin slices, and then appears red by transmitted light.
and easily pulverised. It crystallises by sublimation in large brillia
plates, or in elongated octahedrons. Finer crystals are obtained from
exposing to the air an aqueous solution of hydriodic acid, or a solution of
The crystals belong to the trimetric system, having their axes in the rat

Iodine melts at 107° C. (224·6 F.), and solidifies in a lamellated m
It boils (when immersed in strong sulphuric acid) between 175° and
356° F.). In the open air it volatilises at ordinary temperatures, e
moist, diffusing an odour having considerable resemblance to that o
easily distinguished from it. Its vapour has a splendid violet colour (h
of the substance). The saturated vapour is so deep-coloured, that a strat
thick is impervious to daylight or candlelight. The colour is seen to g
when a quantity of iodine is thrown upon a hot brick. Iodine-vapou
heaviest of gaseous bodies, its specific gravity referred to air as uni
according to the experiments of Dumas, and 127 × 0·0693 = 8·801
from the atomic weight.

Iodine dissolves but sparingly in *water*, 1 pt. of iodine requiring 7,00
to dissolve it at ordinary temperatures. *Alcohol* and *ether* dissolve it
forming dark brown liquids. The alcoholic solution yields crystals of
poration, and is decomposed by water, which throws down the iodi
powder. Iodine also dissolves with facility in water containing solu
nitrate or *chloride of ammonium*, the solutions having a deep red co
containing 20 grains of iodine and 30 grains of iodide of potassium
water, is known as Lugol's solution, and is preferred in medicine t
tincture, because it is not decomposed by dilution with water. Iodin
sulphide of carbon, a very small quantity of it being sufficient to impart
very rich violet tint.

Iodine in its chemical reactions resembles chlorine and bromine, but i
and is displaced from most of its combinations by either of those bodie
colouring matters but slowly, and does not decompose water under the
sun's rays. It exerts a destructive action on organic tissues, producing
brown stain on the skin, paper, &c. This colour disappears after a w
influence of heat, if the contact has not been too much prolonged.

Iodine forms with *starch* a compound of a deep blue colour, soluble
but insoluble in acid and alkaline solutions. Its production affords
delicate test of the presence of iodine. If the iodine is in the free
colour is at once produced, but if it is in combination as a soluble iodid
takes place till the iodine is liberated by chlorine or nitrous acid (see Iod
p. 287). The blue compound is decolorised at a temperature of 70° o
176° F.), but recovers its colour as the liquid cools.

Iodine is employed in the laboratory for many chemical preparations,
starch. It was first introduced into medicine by Coindet of Geneva, w
with success for the treatment of goitre, either dissolved in alcohol, o
iodide of potassium, or as iodide of sodium; and since that applicatio
waters to which the virtue of curing goitre was ascribed, have been fo
iodine (Boussingault, Ann. Ch. Phys. liv. 163). On the other han
(Phil. Mag. [4] vi. 237) failed to detect iodine in the air and water of
tainous districts which are peculiarly free from goitre. Iodine appears t
action in causing the absorption of glandular swellings, and is also ad

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tonic. Iodine swallowed in the solid state causes ulceration of the mucous membrane of the stomach, and death.

Iodine is extensively used in photography. The sensitive film of the daguerreotype plate consists of iodide of silver, produced by exposing a polished plate of the metal to the action of iodine-vapour; and surfaces of paper, collodion, albumin, &c. are rendered capable of taking photographic pictures by dipping them first in a solution of nitrate of silver and then in iodide (or sometimes bromide) of potassium.

IODINE, BROMIDES OF. Iodine forms with bromine a solid, volatile, crystalline compound, probably a protobromide, IBr (Balard), and with excess of bromine, a dark brown liquid, soluble in water, probably a pentabromide, IBr^5 (Löwig). On exposing the pentabromide together with a small quantity of water to a temperature below 0°, a crystalline hydrate is formed which at + 4° is resolved into water and bromide of iodine. (Löwig.)

IODINE, CHLORIDES OF. Iodine unites directly with chlorine, forming a protochloride and a trichloride, and perhaps also a pentachloride. There is also a tetrachloride produced by decomposition of the protochloride.

Protochloride. ICl.—Of this compound there are said to be two modifications, one liquid at common temperatures, the other solid; but the differences observed are perhaps due to the presence of small quantities of foreign substances, or to slight variations in the proportions of the chlorine and iodine. It is obtained:—1. By passing dry chlorine gas over dry iodine till the whole is liquefied, but no longer.—2. By distilling iodine with chlorate of potassium, oxygen being then evolved, the protochloride distilling over, and a mixture of chloride, iodate, and perchlorate of potassium remaining behind (Berzelius):

$$I^2 + 3KClO^3 = KClO^4 + KIO^3 + KCl + O^2 + ICl.$$

The protochloride of iodine obtained by either of these processes is described as a reddish-brown oily liquid, and nothing is said about its solidification (*Gmelin's Handbook*, ii. 346). According to J. Trapp also (J. pr. Chem. lxiii. 108), the liquid protochloride obtained as above does not solidify. But P. Schützenberger (*Zeitschr. Chem. Pharm.* 1862, p. 1) by passing dry chlorine in the cold over dry iodine (100 grms.) till it was liquefied, then adding more iodine (50 grms.), distilling between 100° and 102°, and rectifying between the same limits, obtained a liquid which crystallised in long needles when cooled to 10° in an open vessel, but if sealed up in a flask before it had time to solidify, retained its fluidity for 24 hours even when cooled to between 2° and 3°, and when the flask was opened, solidified suddenly, with rise of temperature, like a supersaturated solution of Glauber's salt. The crystals when exposed to the air, melted at 30° and solidified again at 25°. A similar result was obtained by introducing 31 grms. of iodine into a flask containing 8·7 grms. of chlorine (quantities proportional to the atomic weights). The whole of the chlorine was rapidly absorbed, and a liquid was formed which remained unaltered for many hours at 5° or 6°, but ultimately solidified completely.—By distilling iodine with chlorate of potassium, Schützenberger likewise obtained a dark-coloured liquid which quickly crystallised.

Trapp (*loc. cit.*) has also obtained the protochloride of iodine in the solid state by strongly heating iodine in a retort till it melted, and passing a stream of dry chlorine into the iodine-vapour till all the iodine had disappeared; the upper part of the retort then became filled with a thick red-brown vapour, and the solid protochloride of iodine collected in the receiver in large, hyacinth-red, transparent prisms and tables, which melted at 25° to a red-brown oily liquid.

Protochloride of iodine is very volatile; has a pungent odour of chlorine and iodine; attacks the eyes strongly; tastes slightly acid, strongly astringent and biting; stains the skin deep-yellow, and produces smarting. It decolorises *indigo* and *litmus*, but does not give a blue colour with *starch*. It deliquesces in the air, and according to Gay-Lussac, dissolves easily in *water* without decomposition; according to Schützenberger, on the other hand, it is decomposed by water, yielding iodic and hydrochloric acids, with separation of iodine, and formation of an iodised compound, which remains dissolved in the water, but may be extracted therefrom by ether. The protochloride dissolves in *alcohol* and in *ether*, forming yellow solutions.

Protochloride of iodine sometimes decomposes spontaneously into the tetrachloride and free iodine: $4ICl = ICl^4 + I^4$ (Kämmerer, J. pr. Chem. lxxxiii. 83).—When heated, it gives off the trichloride, leaving a residue of pure iodine: $3ICl = ICl^3 + I^2$ (Kane, Phil. Mag. [3] x. 430). *Sulphurous* and *sulphydric acids* decompose it with separation of iodine. With aqueous solutions of the fixed *alkalis* it yields a chloride and iodate and free iodine:

$$6KHO + 5ICl = 5KCl + KIO^3 + 3H^2O + I^4,$$

the iodine however dissolving in excess of the alkali in the form of iodide and iodate.

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—With aqueous or alcoholic *ammonia*, it yields various iodamides (the so-called iodides of nitrogen (p. 289), according to the proportions used and the manner in which the reaction takes place, *e.g.*:

$$3ICl + NH^3 = 3HCl + NI^3. \text{ (Mitscherlich.)}$$
$$2ICl + NH^3 = 2HCl + NHI^2.$$
$$ICl + NH^3 = HCl + NH^2I.$$
$$3ICl + 2NH^3 = 3HCl + NI^3.NH^3. \text{ (Bunsen.)}$$

Mercuric chloride added to a concentrated aqueous solution of protochloride of iodine throws down mercuric iodide, leaving trichloride of iodine in solution (Kane):

$$4ICl + HgCl^2 = HgI^2 + 2ICl^3.$$

Stannous chloride added in small quantity to the concentrated aqueous solution, precipitates iodine, and is converted into stannic chloride: but on adding a larger quantity of the stannous chloride, the iodine disappears, and stannous iodide separates in brilliant orange-coloured needles (Kane):

$$2ICl + SnCl^2 = I^2 + SnCl^4.$$
$$2ICl + 3SnCl^2 = SnI^2 + 2SnCl^4.$$

Protochloride of iodine acts very readily on many organic compounds, the chlorine taking up an atom of hydrogen to form hydrochloric acid, and the iodine taking its place. In this way, many iodine-substitution-compounds may be obtained which could not be formed by the action of iodine alone; *e.g.*, iodopyromeconic acid, $C^5HI^2O^2$, from *pyromeconic acid*, $C^5H^4O^2$ (J. Brown, Edinb. Phil. Trans. xxi. [1] 49); mono- and di-iodophenic acids, from *phenic acid*, C^6H^6O (Sengenwald, Compt. rend. liv. 197). On the *alcoholic hydrides*, hydride of heptyl for example, protochloride of iodine acts in a manner opposite to that just mentioned, converting them into chlorides, with elimination of hydriodic acid (Schorlemmer, p. 144). In some cases, chloride of iodine unites directly with an organic compound, with *ethylene*, for example, forming chloriodide of ethylene, C^2H^4ClI (Maxwell Simpson, Proc. Roy. Soc. xii. 278). According to Geuther, however (Ann. Ch. Pharm. cxxiii. 123), when dry coal-gas is passed over fused protochloride of iodine, the ethylene contained in it is converted into dichloride of ethylene:

$$C^2H^4 + 2ICl = C^2H^4Cl^2 + I^2.$$

From iodised organic compounds it sometimes takes away one or more atoms of iodine, replacing them by chlorine; thus it converts *iodide of ethyl* into chloride of ethyl (Geuther):

$$C^2H^5I + ICl = C^2H^5Cl + I^2;$$

di-iodide of ethylene into chloriodide of ethylene (Maxwell Simpson):

$$C^2H^4I^2 + ICl = C^2H^4ICl + I^2;$$

or into dichloride of ethylene (Geuther):

$$C^2H^4I^2 + 2ICl = C^2H^4Cl^2 + I^4.$$

Benzene, C^6H^6, is violently attacked by protochloride of iodine, yielding chiefly crystalline chlorinated products of high boiling point, together with iodated bodies and free iodine.

Trichloride. ICl^3.—This compound is produced:—1. By treating iodine at a gentle heat with excess of chlorine gas.—2. By introducing finely divided iodic anhydride into dry hydrochloric acid gas; the mass then liquefies and boils, and on cooling deposits trichloride of iodine in long needles (Serullas):

$$I^2O^5 + 10HCl = 2ICl^3 + 5H^2O + Cl^4.$$

Also by mixing the crystallised iodic acid or anhydride with strong hydrochloric acid, the trichloride then crystallising out. (Soubeiran.)

Trichloride of iodine is orange-yellow, and crystallises on cooling after fusion in long needles (Serullas). It acts on other substances in the same manner as the protochloride (Kane); decolorises solution of indigo (Gay-Lussac); does not turn starch blue, except on the addition of an aqueous solution of stannous chloride, or other dechlorinating substance, which sets the iodine free.

It melts at a temperature between 20° and 25°, evolving chlorine gas, which it again absorbs on cooling (Serullas). In contact with a very small quantity of *water*, it is partly resolved into an insoluble yellowish portion (probably a mixture of trichloride of iodine and iodic anhydride), and a solution of protochloride of iodine and hydrochloric acid (Serullas):

$$4ICl^3 + 5H^2O = 10HCl + I^2O^5 + 2ICl.$$

Trichloride of iodine is less readily dissolved by *water* than the protochloride, the

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ither as aqueous trichloride of iodine—which is
s a mixture of hydrochloric acid and iodic acid
ure of hydrochloric acid and an acid of iodine
dous acid):

$$= 15HCl + 3HIO^3 + I^2.$$
Iodic acid.

$$= 3HCl + HIO^2.$$
Iodous acid.

sing chlorine gas to saturation, through 1 pt. of
he mixture being kept cool, and the excess of
urrent of atmospheric air. The solution, when
ly as possible, has a bright yellow colour and
f chlorine to 1 atom of iodine, because the water
all quantity of hydrochloric acid and iodic acid
le of iodine may also be prepared by precipitating
loride with mercuric chloride, and distilling the
cipitated iodide of mercury.
oride of iodine is gradually mixed with sulphuric
chloride separates in the form of a white curdy
orange-yellow colour; on heating the mixture, it
liquid cools; on distilling the mixture, the tri-
ther does not separate trichloride of iodine from
protochloride of iodine is also present, the ether
with it, provided the solution is not too dilute
of trichloride of iodine neutralised with a fixed
d a precipitate of iodine, which redissolves in ar
and iodate (Liebig):

$$15KCl + 3KIO^3 + I^2 + 9H^2O.$$

an aqueous solution of neutral *iodate of potassium*
e of potassium is precipitated (Serullas). An
odine agitated with a small quantity of *oxide of*
dic acid; when a larger quantity of oxide of silver
d with iodate (Serullas), and iodide of silver is

$$^2O = 9AgCl + AgI + 2HIO^3.$$

trichloride of iodine into chloride and iodide of
trichloride of iodine is mixed with a small
oride, a precipitate of iodine is obtained, soluble in

etallic chlorides. (Filhol.)
d by spontaneous decomposition of the liquid
Crystallises in red octahedrons, the free iodine
g dissolved in the mother-liquor. (Kämmerer,

wn in the free state. Dry iodine cannot be made to
iebig). Iodine diffused in 4 pts. of water does
f chlorine, and the yellow solution obtained yields a
with alkalis (Soubeiran). The same results are
r is 8 or 10 times as great as that of the iodine.
rough a still larger quantity of water, 20 pts. for
mbines with 5 atoms of chlorine; the solution in
ured yellow from excess of chlorine, which may be
bits all the properties of a solution of hydrochloric
an, L. Thompson):

$$H^2O = 10HCl + 2HIO^3.$$

ned on mixing dilute hydrochloric and iodic acids.
wly decolorises a solution of indigo (Gay-Lussac).
richloride of iodine from it and liberates chlorine.

ND ESTIMATION OF. Iodine in the free
let vapour which it gives off when heated, and by
h for this purpose should be perfectly colourless; it

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may be prepared by boiling potato-starch or arrow-root with water and leaving it to cool. To obtain a delicate reagent, Béchamp (Zeitschr. Analyt. Chem. i. 466), recommends the following mode of preparation. Gelatinous starch is boiled with a quantity of concentrated potash-ley equal to $\frac{1}{10}$ of the weight of the dry starch contained in it, till it has become perfectly fluid; the liquid is then diluted with water, supersaturated with acetic acid, and precipitated with alcohol; and the bulky precipitate is boiled first with alcohol of 60 vol. per cent. then washed, first with alcohol acidulated with sulphuric acid, then with pure alcohol of the same strength, and dried. For use, the dried preparation is to be suspended in hot water.

When iodine exists in solution in the form of hydriodic acid or a metallic iodide, it may be separated by the addition of chlorine-water, sulphuric acid, or nitric acid, and will then give the blue colour with starch. When chlorine-water is used, care must be taken not to add an excess, as a chloride of iodine will then be formed which will not exhibit the starch reaction. (See IODIDES, p. 287.)

The methods of detecting iodine in insoluble iodides, and in presence of oxygen, sulphur, phosphorus, &c., are the same as those employed when it is to be estimated quantitatively.

Quantitative Estimation.—Iodine in the free state is best determined by means of a standard solution of sulphurous acid (see ANALYSIS, VOLUMETRIC, i. 265). When it occurs in the solution in the form of hydriodic acid or a metallic iodide, it may either be set free by *chlorine-water* and estimated volumetrically in the same manner; or it may be precipitated by *nitrate of silver* in the same manner as chlorine and bromine (i. 677, 903). 100 pts. of iodide of silver correspond to 54·128 pts. of iodine.

It may also be precipitated as iodide of palladium, by mixing the solution with chloride or *nitrate of palladium.* A black precipitate then falls, which settles down slowly but completely, and when ignited, leaves metallic palladium, 100 pts. of which are equivalent to 239·62 pts. of iodine.

This last method of precipitation serves also to separate iodine from bromine and chlorine. If the chlorine is also to be estimated, the precipitation must of course be made with nitrate of palladium, not with chloride. If bromine is present without chlorine, the iodine must be precipitated with chloride of palladium, because the nitrate would precipitate bromine as well as iodine; the precipitation of the bromine may however be prevented by the addition of a soluble chloride. To estimate the chlorine and bromine in the filtered liquid, the excess of palladium is removed by sulphydric acid and the excess of the latter by means of nitric acid or a ferric salt. The bromine and chlorine may then be precipitated by nitrate of silver, and the precipitate treated in the manner already described (i. 903). Iodine may also be estimated in presence of chlorine by the method already described (i. 678) for the estimation of bromine, viz., by precipitating the two elements with nitrate of silver and heating the silver precipitate in a stream of chlorine. The quantity of iodine is equal to the loss of weight multiplied by $\frac{127}{127 - 35{\cdot}5} = 1{\cdot}28$.

A precisely similar method may be applied to the determination of iodine in presence of bromine, the precipitate of iodide and bromide of silver being ignited in bromine-vapour, and the loss of weight multiplied by $\frac{127}{127 - 80} = 2{\cdot}70$.

For other methods of estimating iodine in presence of chlorine and bromine, see i. 678.

The method of decomposing *insoluble iodides*, so as to obtain the iodine in solution, are similar to those adopted for insoluble bromides (i. 678).

Iodates and *periodates* are reduced to iodides by the action of sulphurous or sulphydric acid. To decompose them by ignition would not give accurate results, as a portion of the iodine would be driven off.

The compounds of iodine with *phosphorus*, *arsenic* and *antimony* may be decomposed and analysed by treating them with water or aqueous alkalis, whereby the iodine is converted into hydriodic acid, and may then be precipitated with nitrate of silver from a solution acidulated with nitric acid. The iodides of *sulphur* are most readily analysed by heating them in a combustion-tube with nitrate of potassium and carbonate of sodium, whereby the iodine and sulphur are converted into metallic iodide and sulphate. (Guthrie, Chem. Soc. J. xiv. 59.)

Iodine in *organic compounds* may be estimated in the same manner as chlorine (i. 247). In the more easily decomposible compounds, such as the iodated organic acids, the iodine may also be determined by decomposing the compound with water and sodium-amalgam, then acidulating the solution with nitric acid, and precipitating with nitrate of silver. The same method may be applied to the corresponding bromine- and chlorine-compounds. (Kekulé, Ann. Ch. Pharm. Suppl. i. 338.)

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rlier attempts to determine the atomic weight of Lussac and Berzelius, gave results varying from r below those obtained by more recent determina- potassium and iodate of silver, and weighing the ber 126·47; but the result is not quite exact, be- ly decomposed by ignition.

been made by Marignac (Bibl. univ. de Genève, arm. cv. 93). Marignac determined the quantity recipitating a known quantity of silver from the e closely agreeing experiments, that 100 pts. silver f the nitrate by 153·74 pts. iodide of potassium; = 108 : x gives 166·04 for the atomic weight of ned by 39·2, the atomic weight of potassium, gives

ignac determined the quantity of iodide of silver om a known weight of silver dissolved in nitric agreeing experiments, he found that 100 pts. of nce the atomic weight of iodide of silver is

ninished by 108, gives for iodine the number

silver by ignition in a stream of chlorine, and roduced. In one experiment 3·520 grms. iodide ther 7·011 iodide gave 4·281 chloride. Both these ght 127, which is the number now adopted.

GEN-ACIDS OF. The series of oxidised com- plete as that of chlorine. The following have been less accuracy:

	Oxides or Anhydrides.	
HIO		
	Millon's Sub-hypo-iodic acid	$I^{10}O^{19}$
	Periodic oxide (Millon's Hypo-iodic acid)	IO^2 or I^2O^4
	Intermediate Iodic oxide	I^6O^{13}
HIO^3	Iodic anhydride	I^2O^5
HIO^4	Periodic anhydride	I^2O^7.

e composition has been established with certainty ir corresponding anhydrides and salts. The ex- riodic oxide has been rendered probable by experi- bed. The remaining oxides, $I^{10}O^{19}$ and I^6O^{13}, are ubstances analysed were perhaps impure periodic ic anhydride containing excess of iodine.

odous acid. HIO?

nding to hypochlorous acid appears to exist, but et been obtained in definite form. According to eriodate gives off part of its oxygen when ignited, which in cold water possesses bleaching properties Ann. xi. 162; xvii. 481), by dissolving iodine in iquid began to show colour, and evaporating at a sisting of $Na^2I^2O^3.10H^2O$, which however might lide and iodate of sodium: $NaI.NaIO^3\,10H^2O$; in hol is resolved into soluble iodide and insoluble 96), by distilling iodine with anhydrous peroxide which he regarded as hypo-iodous acid, or rather

Chem. lxxxiv. 385), when 1 at. iodine is dissolved h, the formation of iodate of potassium does not ded by that of hypo-iodite of potassium, just as in which has the odour of saffron, and exhibits ypochlorites, is however very unstable, the hypo- rdinary temperatures, and instantly at the boiling $O = 2KI + KIO^3$. Schönbein also finds that by the action of iodine on excess of ammonia.

enthal (J. pr. Chem. lxxxvi. 216), hypo-iodous ned by the action of carbonate of sodium (or other

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alkaline liquid) on trichloride of iodine, which is yellow, reddens benzene, colours starch blue, and contains a salt having the composition NaI^3O or $NaIO.I^2$, that is, hypo-iodite of sodium with 2 atoms of free iodine, on the removal of which, either by excess of alkali, sulphurous acid, benzene, or other reagents, the hypo-iodite of potassium is immediately resolved into iodide and iodate. The alkaline solution of hypo-iodous acid is decomposed by iodide of potassium, yielding free alkali and free iodine, according to the equation:

$$KI + NaIO + H^2O = KHO + NaHO + I^2.$$

The subject requires further examination.

Periodic oxide, IO^2, and Oxides nearly allied to it in composition.

Periodic oxide is obtained, according to Millon, by treating with dilute alcohol the powder (p. 299) produced by the action of fuming nitric acid on iodine, regarded by Kämmerer as nitroso-iodic anhydride, $I^2O^4(NO)^2$.

When iodic anhydride is heated with 5 pts. of strong sulphuric acid, till a few bubbles of oxygen are given off, a scaly sulphur-yellow substance is formed, which appears to consist of $4I^2O^5.2IO^2.SO^4H^2$. If the boiling be continued, the evolution of oxygen goes on, and crystals are formed, having a much deeper yellow colour than the preceding, and apparently consisting of $2I^2O^5.IO^2.SO^4H$. Water decomposes both these compounds into sulphuric acid, iodic acid, and iodine. By continuing the action of the sulphuric acid till iodine begins to escape as well as oxygen, two other compounds are formed, to which Millon assigns the formulæ $2IO^2.2SO^3.H^2O$ and $I^{10}O^{19}.10SO^3.H^2O$. These substances, subjected to the action of moist air, appear to yield the compounds IO^2 and $I^{10}O^{19}$ in the free state. To the latter, Millon gives the name *sub-hypo-iodic acid [anhydride]*.

When sulphurous anhydride is allowed to act upon iodic anhydride longer than is required to form the compound $5I^2O^5.SO^3$ (p. 299), a large quantity of iodine is separated, and a lumpy adhesive mass is formed, which, if left for a day standing over water in a bell-jar, then washed with alcohol and with water, leaves an oxide of iodine containing I^6O^{13}, contaminated with a small quantity of sulphuric acid. It is a brown-yellow powder which does not decompose in the air, but absorbs a small quantity of water from it. Dilute nitric acid dissolves it, with separation of iodine; fuming nitric acid converts it into iodic acid. When heated to 100°, it splits up into iodine and iodic anhydride: $5I^6O^{13} = 13I^2O^5 + I^4$. Water decomposes it slowly at ordinary temperatures, quickly at 100°, into iodine and iodic acid.

Aqueous alkalis act in the same manner; but alcoholic alkalis do not act upon it at ordinary temperatures. This circumstance distinguishes it from the oxides IO^2 and $I^{10}O^{19}$ above-mentioned, which, according to Millon, form with alcoholic potash, brick-red easily decomposible salts. Absolute alcohol, ether, acetic ether, and sulphide of carbon are likewise without action on the oxide I^6O^{13}, even at the boiling heat. (Kämmerer, J. pr. Chem. lxxxiii. 72.)

Iodic acid, Anhydride and Salts.

Iodic Acid. HIO^3. (Gm. ii. 253.)—This acid is produced by the action of oxidising agents upon iodine in presence of water or alkalis. According to Pettenkofer (Jahresber. 1857, p. 581), it is sometimes found in commercial nitric acid (the iodine being doubtless derived from the Chili saltpetre used in the preparation). According to Riche (Compt. rend. xlvi. 348), it is produced by the electrolysis of aqueous hydriodic acid or aqueous iodine; in the former case, the hydriodic acid is simply oxidised to HIO^3 by oxygen evolved by the decomposition of the water; in the latter the iodine is first converted into hydriodic acid, which is then oxidised in the manner just mentioned. It is also produced by the action of iodine on chloric or bromic acid. (Kämmerer, J. pr. Chem. lxxxv. 452.)

Preparation.—1. Small quantities of iodic acid are conveniently prepared by heating iodine with the strongest nitric acid free from nitrous acid in a wide glass tube, and leaving the liquid to cool. Iodic acid is then deposited in crystals (Connel). Jacquelain (Ann. Ch. Phys. [3] xxx. 332) recommends this as the best mode of preparing iodic acid in all cases. He heats 5 grms. of dry iodine in a flask with 200 grms. nitric acid of specific gravity 1·5 to 60° for an hour; decants the supernatant liquids (the upper consisting of nitric acid containing pernitric oxide, the lower of a red-brown solution of iodine in nitric acid) from the separated iodic acid; distils these liquids down to one-sixth; and gently heats the residue, together with the crystallised iodic acid, in a vessel in which it is protected from dust; iodic anhydride then separates in nacreous crystals.—2. For preparing larger quantities, Liebig's method is, however, generally preferred. It consists in suspending an ounce or two of pulverised iodine in a pound of water, and passing a stream of chlorine through the liquid, till the iodine is completely dissolved:

$$6H^2O + 5Cl^2 + I^2 = 10HCl + 2HIO^3.$$

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The brown strongly acid liquid is then slightly supersaturated with carbonate of sodium, whereby a considerable quantity of iodine is precipitated, which may be collected on a filter, then suspended in water, and treated with chlorine as before. The filtered solution contains iodate and chloride of sodium, with a trace of carbonate, which may be neutralised by hydrochloric acid. On afterwards adding chloride of barium to the filtered liquid as long as a precipitate is formed, the whole of the iodic acid is thrown down as iodate of barium, which may be collected on a filter, dried, and then decomposed by boiling it for half an hour with 2 pts. of oil of vitriol diluted with 10 or 12 pts. of water. The iodic acid thus liberated dissolves in the water, and the solution filtered from the sulphate of barium and evaporated at a gentle heat, yields the acid in the form of a crystalline mass. Kämmerer (J. pr. Chem. lxxix. 94) dissolves iodine in hot saturated baryta-water; filters the solution of iodide of barium from the separated iodate; passes chlorine through the filtrate (which at first precipitates iodine, but in a state of very fine division, so that it is very quickly oxidised), and thereby converts the whole of the iodide of barium into iodate, from which the iodic acid may then be separated by sulphuric acid.—3. Another very good method of preparing the acid is to digest 4 pts. of iodine with 7·5 pts. of chlorate of potassium in 40 pts. of water acidulated with 10 pts. of nitric acid, and heat the liquid sufficiently to cause rapid evolution of chlorine. In a short time the iodine is completely oxidised, and the iodic acid thus formed may be precipitated by baryta, and separated again by sulphuric acid. The largest crystals are obtained when the solution contains a slight excess of sulphuric acid.

The crystallised acid, HIO^3 or $I^2O^5.H^2O$, when exposed to a heat of 130°, or digested in absolute alcohol, is partly resolved into water and iodic anhydride, which remains combined with the iodic acid, forming the compound $I^2O^5.HIO^3$ or $3I^2O^5.H^2O$:

$$3HIO^3 = I^2O^5.HIO^3 + H^2O,$$

which at 170° suffers further decomposition, yielding water and iodic anhydride.

Iodic anhydride, I^2O^5, crystallises in forms belonging to the trimetric system, and often reduced to the tabular form by the predominance of two parallel faces ∞P. For P the ratio of the principal to the secondary axes is 1 : 0·7586 : 0·7122. Angles P : P in the terminal edges = 99° 22′, and 105° 12′; in the lateral edges = 125° 7′; ∞P : ∞P = 93° 37′. The pyramidal faces occur sphenoïdo-hemihedrally. Cleavage perfect parallel to P∞; imperfect parallel to P∞ (Schabus, *Bestimmung der Krystallgestalten in chemischen Laboratorien erzeugter Produkte*, Wien, 1855; Jahresber. 1854, p. 310). Specific gravity of the crystals = 4·250 (Filhol, Ann. Ch. Phys. [3] xi. 415). At the temperature of boiling olive-oil, the anhydride is completely resolved into iodine and oxygen. It dissolves in water, forming iodic acid.

Pulverised iodic anhydride is reduced at ordinary temperatures by a small quantity of *sulphurous anhydride*, yielding sulphuric anhydride and free iodine; by continued action of sulphurous anhydride at 100°, it is converted into a light yellow granulo-crystalline mass, consisting of an iodosulphuric anhydride, $5I^2O^5.SO^3$. This compound is quickly decomposed by contact with air and water, with separation of iodine. By absolute alcohol or ether, it is resolved into I^2O^5 and SO^3; and by alcoholic potash it is converted into iodate and sulphate of potassium. Strong sulphuric acid does not act upon it at common temperatures; hydrochloric acid dissolves it, with evolution of chlorine and formation of chloride of iodine. By still longer exposure to the action of sulphurous anhydride, the iodic anhydride is completely decomposed, yielding a large quantity of iodine, and an adhesive mass containing an oxide of iodine, I^6O^{13} (p. 298).

Nitro-iodic anhydride, $I^2O^4(NO)^2$?—Millon (Ann. Ch. Phys. [3] xii. 330), by triturating iodine with strong nitric acid, obtained a yellow powder which he regarded as a compound of nitric acid with periodic oxide, IO^3; it was resolved by water into nitric acid, iodic acid, and iodine, and when treated with dilute alcohol yielded a small quantity of periodic oxide, IO^2 (Millon's *hypo-iodic acid*). Kämmerer (J. pr. Chem. lxxxiii. 72) has obtained the same substance by Millon's method, also by treating iodine with a mixture of fuming nitric and strong sulphuric acids, and assigns to it the composition above given. He finds that it is decomposed by drying over lime, with evolution of nitric oxide, and that, when dried in an atmosphere of carbonic anhydride, it splits up into nitric oxide and periodic oxide. It is decomposed by water and by aqueous acids and alkalis; hydrochloric acid dissolves it, with evolution of chlorine and formation of chloride of iodine. Alcohol, ether, and acetic ether are violently attacked, often with incandescence, even by small quantities of the compound. By exposure to moist air at common temperatures, it is decomposed into iodine, iodic acid, and nitric acid; in dry and very cold air it remains unaltered for a long time. It dissolves slowly, and without decomposition, in strong sulphuric acid, and sometimes separates from the solution spontaneously, but is easily precipitated on scratching the sides of the vessel with a glass rod, or adding fuming nitric acid to the solution. The sulphuric acid solution, when boiled, gives off a large quantity of nitric oxide.

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Iodic acid, HIO^3, crystallises from a strong aqueous solution in transparent six-sided tables without water of crystallisation (Serullas, Marignac). According to Rammelsberg (Pogg. Ann. xc. 12) the crystals are trimetric, the ratio of the brachydiagonal, macrodiagonal, and principal axis being = 0·58905 : 1 : 1·1903. They exhibit the faces ∞P, $\breve{P}\infty$, oP, with $\frac{1}{2}\breve{P}\infty$ and $2\breve{P}\infty$ subordinate. In the brachydiagonal principal section $\infty P : \infty P = 119° 0'$; $\breve{P}\infty : \breve{P}\infty = 80° 4'$. The crystals are transparent and have a vitreous lustre; they are generally either tabular by predominance of oP, or elongated in the direction of the brachydiagonal; cleavage distinct parallel to oP, less distinct parallel to ∞P. According to Marignac (Jahresber. 1856, p. 296. 1857, p. 124) iodic acid crystallises from aqueous solution at 50°—60° for the most part in the form determined by Schabus for the anhydride,* less abundantly in the form just described as determined by Rammelsberg. Marignac finds, however, different values for some of the angles, viz., $\infty P : \infty P$ in the brachydiagonal principal section = 114° 46'; $\breve{P}\infty : \breve{P}\infty$ in the same = 79° 38'. Kämmerer (J. pr. Chem. lxxxv. 452) has obtained a hydrate of iodic acid, $2HIO^3.9H^2O$, which crystallises at 17° in beautiful hexagonal tables.

Iodic acid is very soluble in *water*, slightly soluble in *alcohol*. The aqueous acid bleaches litmus paper after first reddening it. It is easily decomposed by *deoxidising agents*, yielding in the first instance hydriodic acid, which then, with the remaining iodic acid, forms water and free iodine:

$$HIO^3 + 5HI = 3H^2O + I^6.$$

Hence aqueous iodic acid, though it does not of itself impart a blue colour to starch, produces this colour immediately on the addition of hydriodic, sulphydric or sulphurous acid, stannous chloride, vegetable acids, or other deoxidising agents. In some cases however an excess of the reducing agent converts the free iodine into hydriodic acid and destroys the blue colour: thus with sulphurous acid:

$$\underset{\text{Sulphurous acid.}}{H^2SO^3} + I^2 + H^2O = 2HI + \underset{\text{Sulphuric acid.}}{H^2SO^4}.$$

Nitric oxide gas reduces aqueous iodic acid at ordinary temperatures (Kämmerer). The acid heated in sealed tubes with *sulphide of carbon* is reduced to hydriodic acid, in like manner iodate of potassium to iodide (Schlagdenhauffen, J. Pharm [3] xxxiv. 175). *Ferrous sulphate* does not of itself appear to reduce iodic acid, but on addition of caustic soda and subsequent supersaturation with sulphuric acid, iodine is set free. In this case, it may be supposed that the ferrous sulphate first separates iodine, which is taken up by the soda-ley, forming iodide and iodate of sodium, and that, on addition of sulphuric acid, iodic and hydriodic acids are set free, which act upon each other in the way above mentioned, yielding free iodine (Hempel, Ann. Ch. Pharm. cvii. 97). Aqueous iodic acid yields by *electrolysis*, oxygen at the positive, and iodine at the negative pole, the separation of the latter being due to the action of nascent hydrogen resulting from the decomposition of the water. According to Buff (Ann. Ch. Pharm. cx. 257), the iodic acid is resolved by the current into H and IO^3, which latter is decomposed by the water, yielding HIO^3 and free oxygen.

Iodates. Iodic acid is monobasic, like chloric and bromic acids, the general formula of its normal salts being

$$MIO^3 = \left.\begin{matrix} IO^2 \\ M \end{matrix}\right\} O \text{ or } M^2O.I^2O^5.$$

But there are likewise acid iodates, or more properly anhydro-iodates, which may be regarded as compounds of the normal iodates with one or more molecules of iodic anhydride: thus there are three iodates of potassium, having the following formulæ:

Normal iodate of potassium	$2KIO^3$ or $K^2O.I^2O^5$.
Di-iodate of potassium . . .	$2KIO^3.I^2O^5$ or $K^2O.2I^2O^5$.
Tri-iodate of potassium . . .	$2KIO^3.2I^2O^5$ or $K^2O.3^2IO^5$.

The normal iodates are obtained: 1. By bringing iodine in contact with an alkali and water, and removing the metallic iodide formed at the same time, by digestion in alcohol.—2. By direct mixture of iodic acid with a salifiable base.—3. By bringing the aqueous acid in contact with metals.

Most iodates are insoluble or sparingly soluble in water, the only easily soluble iodates being the ammonium-, potassium-, and sodium-salts. The solutions of these salts give with somewhat concentrated solutions of strontium- and calcium-salts, and with dilute solutions of barium-, lead-, and silver-salts, white crystalline, granular precipitates. The silver-precipitate is easily soluble in ammonia, very slightly soluble in nitric acid.

The normal iodates, when heated, either give up 3 atoms of oxygen, but no iodine, and are converted into metallic iodides (*e. g.* $KIO^3 - O^3 = KI$), or they part with their

* The crystals examined by Schabus probably consisted of the acid, not of the anhydride.

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iodine and 5 atoms of oxygen, and are reduced to metallic oxides (*e.g.* $BaO.I^2O^5 - O^5 - I^2 = BaO$), accordingly as the metal has greater affinity for iodine or for oxygen. Some iodates detonate when heated with combustible bodies, *e.g.* on red-hot coals,—sometimes even when merely struck; but the detonation is much weaker than that produced by chlorates or nitrates. The aqueous solution of an iodate mixed with sulphurous acid yields iodine and sulphuric acid, part of which combines with the base (Gay-Lussac). With sulphydric acid, the solution of an iodate yields hydriodic acid, water, sulphur, and a sulphate (H. Rose); with hydriodic acid, or with a dissolved iodide mixed with an acid to liberate the hydriodic acid, it yields a metallic iodide, iodine, and water:

$$KIO^3 + 6HI = KI + I^6 + 3H^2O.$$

Iodides and iodates containing weak bases may also decompose one another in solution without the intervention of an acid, yielding an oxide and free iodine: thus with the zinc-salts:

$$Zn(IO^3)^2 + 5ZnI^2 = 6ZnO + I^{10}.$$

With hydrochloric acid, the iodates form water, a metallic chloride, trichloride of iodine, and free chlorine; and the metallic chloride thus produced often enters into combination with the trichloride of iodine (Filhol):

$$KIO^3 + 6HCl = 3H^2O + KCl + ICl^3 + Cl^2.$$

Arsenious acid, with the aid of heat, and likewise dichloride of tin, separate iodine from aqueous solutions of the iodates (Simon). Dilute sulphuric acid at a boiling heat separates the iodic acid from these salts (Gay-Lussac). When an aqueous solution of an iodate is heated with nitric acid, that acid at first takes hold of the base, either wholly or in part; but when the solution is evaporated to dryness and more strongly heated, the less volatile iodic acid drives out the nitric acid. (Penny, Ann. Pharm. xxxvii. 203.)

Iodates heated with strong hydrochloric acid and mercury, or with strong sulphuric acid and ferroso-ferric oxide, impart a blue colour to starch, in consequence of the liberation of iodine.

Iodate of Aluminium. A solution of moist hydrate of alumina in iodic acid evaporated to a syrup and then left over sulphuric acid, yields deliquescent crystals.

Iodate of Ammonium, $(NH^4)IO^3$, is produced by saturating caustic ammonia or carbonate of ammonium with iodic acid or chloride of iodine, and separates as a crystalline powder if the solutions are moderately concentrated. By spontaneous evaporation it is generally said to be obtained in small shining cubes. According to Marignac, however (Ann. Min. [5] ix. 1), the crystals are dimetric, exhibiting the combination $oP . \infty P\infty$, often with P, 2P, ∞P, $P\infty$ and $2P\infty$ subordinate. Angle $oP : P = 124° 54'$; $oP : 2P = 105° 14'$; $oP : P\infty = 134° 37'$; P : P in the terminal edges = 109·7°. That the crystals are not monometric, is also shown by the observation of Marbach (Jahresber. 1855, p. 145), that they act upon polarised light. It decomposes with a hissing noise at 150°, giving off equal volumes of oxygen and nitrogen together with iodine and water. It detonates on glowing coals, and is decomposed by hydrochloric acid, yielding a compound of sal-ammoniac and trichloride of iodine, together with water and free chlorine (Filhol). It dissolves in 38·5 pts. of cold water at 15°, and in 6·9 pts. of boiling water. (Rammelsberg.)

Iodate of Barium, $Ba(IO^3)^2.H^2O$.—This salt is precipitated when iodine is dissolved in baryta-water, iodide of barium remaining in solution. It may also be prepared by saturating an aqueous solution of trichloride of iodine with carbonate of barium or baryta-water, or by precipitating a concentrated solution of chloride of barium with iodate of sodium. The hydrated salt forms a granular powder. From a solution in hot nitric acid, however, it is deposited on cooling or on addition of ammonia, in small crystals (Rammelsberg), which, according to Marignac (*loc. cit.*), are monoclinic and isomorphous with bromate and chlorate of barium, exhibiting the combination $\infty P . (P\infty) . -P\infty$. Angle $\infty P : \infty P$ in the clinodiagonal principal section = 82° 0'; $(P\infty) : (P\infty)$ in the same = 76° 42'; $-P\infty : \infty P = 119° 4'$. The water of crystallisation escapes at a temperature below 200°. On heating the salt more strongly in a porcelain retort, vapour of iodine and oxygen gas are evolved, and a residue is obtained, consisting of basic periodate of barium (Rammelsberg):

$$5Ba(IO^3)^2 = Ba(IO^4)^2.4BaO + 8I + O^{16}.$$

It does not detonate on ignited charcoal, but sometimes exhibits phosphorescence (Gay-Lussac). Hydrochloric acid dissolves it readily, even in the cold, the liquid assuming a dark-yellow colour (probably arising from the formation of a double chloride of iodine and barium) and evolving chlorine. It dissolves with difficulty in warm nitric acid (Rammelsberg). It is soluble in 3,333 pts. of water at 18°, in 625 pts.

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of boiling water (Gay-Lussac), in 1,746 pts. of water at 15°, and in 600 pts. of boiling water (Rammelsberg); the anhydrous salt dissolves in 3,018 pts. water at 13·5°, and in 661 pts. boiling water. (Kremers, Pogg. Ann. xciv. 255.)

Iodate of Bismuth, $2\dot{B}\ddot{i}I^3O^9.H^2O$.—Iodate of sodium added in excess to a solution of bismuth which is no longer precipitated by water, throws down the whole of the bismuth as iodate. The precipitate is nearly insoluble in nitric acid. When ignited it leaves trioxide of bismuth mixed with iodide.

Iodate of Calcium, $Ca(IO^3)^2.5H^2O$.—Crystallises slowly from the mixed solutions of iodate of potassium and chloride of calcium in water (Pleischl), a large proportion of the salt, however, remaining dissolved (Rammelsberg). The crystals are rendered anhydrous by heat. The dry salt gently ignited in a porcelain retort evolves 14·785 per cent. of oxygen and 54·072 of iodine, leaving a residue amounting to 31·143 per cent., and consisting chiefly of pentabasic periodate of calcium; but when heated more strongly, it evolves a still larger amount of oxygen (in the whole 17·176 per cent.) and of iodine (in the whole 62·478 per cent.), and leaves 20·346 per cent. of a mixture of pentabasic periodate and much free lime, which may be separated by water (Rammelsberg, Pogg. Ann. xliv. 576). Iodate of calcium detonates violently on ignited charcoal (Gay-Lussac). When treated with concentrated hydrochloric acid, by which it is readily dissolved, it yields an orange-coloured liquid, smelling of trichloride of iodine, and similar to that yielded by iodate of potassium; it does not, however, give crystals of the double chloride of iodine and calcium (Filhol). The hydrated salt forms four-sided prisms, which effloresce in the air, with partial loss of water, and become anhydrous at a temperature below 200° (Rammelsberg). From a solution acidulated with nitric acid, it separates in trimetric crystals, $\infty P . \infty\breve{P}\infty . 3P . P . oP . 3\breve{P}\infty . 4\breve{P}\infty$. Ratio of axes, $a : b : c = 0{\cdot}4537 : 1 : 0{\cdot}5231$. $\infty P : \infty P$ in the brachydiagonal = 132° 55′; $oP : P = 127° 22'$; $oP : 3P = 104° 17'$ (Senarmont, Marignac, Jahresber. 1857, p. 125). The crystals dissolve in 454 pts. of water at 18°, and in 102 pts. of boiling water (Gay-Lussac); in 253 pts. at 15°, in 75 pts. of boiling water, and much more copiously in nitric acid. From the latter solution the salt is precipitated by ammonia in prisms (Rammelsberg). Alcohol separates the salt from an aqueous solution. (O. Henry.)

Iodate of Cerium, $Ce(IO^3)^2.H^2O$, is a white precipitate which gives off its water at 200°, and leaves pure ceric oxide when ignited.

Iodate of Cobalt, $Co(IO^3)^2.H^2O$, is obtained by dissolving recently precipitated carbonate of cobalt in hot aqueous iodic acid, and separates partly on cooling, partly by evaporation, in violet-red crystalline crusts. Dissolves in 148 pts. of cold and 90 pts. of hot water. Gives off its water of crystallisation at 200°. At a red heat, it gives off iodine and oxygen and leaves cobaltoso-cobaltic oxide, Co^3O^4. Alcohol added to a solution of this salt in sal-ammoniac, throws down a pale-red double salt.

Iodate of Copper.—Iodate of sodium forms with sulphate of copper (after some time only if the solutions are dilute) a greenish-blue precipitate, consisting of $2Cu(IO^3)^2.3H^2O$, which gives off its water at 200° (Rammelsberg). According to Millon, iodic acid forms, even in very dilute solutions of copper-salts, a blue crystalline precipitate composed of $Cu(IO^3)^2.H^2O$, and the same compound is obtained by digesting recently precipitated hydrate or carbonate of copper with iodic acid at ordinary temperatures. When hydrated cupric oxide is washed with boiling water and covered with a sufficient quantity of solution of iodic acid, an olive-coloured powder is obtained which has the same composition as the blue crystals, but requires a temperature about 40° higher to dehydrate it completely. Ignited cupric oxide shaken up with aqueous iodic acid, forms a basic salt, $3[Cu(IO^3)^2.CuO].H^2O$, which however is converted into the olive-coloured salt when the mixture is boiled.

Iodates of Iron.—Ferric Iodate, $Fe^2O^3.2I^2O^5.8H^2O$ or $2Fe^2(IO^3)^6.Fe^2O^3.24H^2O$, is a yellowish-white precipitate obtained by adding iodate of sodium to ammonio-ferric sulphate. The precipitate when dry becomes heavier and assumes a reddish tint. It is soluble in nitric acid, and leaves pure ferric oxide when ignited.

Ferrous Iodate is produced on mixing ferrous sulphate with iodate of potassium, as a white precipitate, which dissolves readily in excess of the ferrous sulphate, but quickly turns brown and decomposes, with evolution of iodine, especially when heated. The brown precipitate dissolves in hydrochloric acid, with evolution of chlorine, and ammonia throws down from the solution a mixture of ferric hydrate and iodide of nitrogen.

Iodate of Lanthanum, $La(IO^3)^2.H^2O$.—Precipitated as a crystalline powder on adding sulphate of lanthanum to aqueous iodic acid. From solution in hot water, it separates on evaporation in white crystalline scales. Gives off its water at a temperature above 110°. (Holzmann, J. pr. Chem. lxxv. 321; Hermann, *ibid.* lxxxii. 385.)

Iodate of Lead, $Pb(IO^3)^2$.—White precipitate, very sparingly soluble in water and

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in nitric acid. Gives off iodine and oxygen when heated, and leaves a mixture of oxide and iodide of lead, from which the oxide is easily dissolved out by acetic acid.

Iodate of Lithium, $LiIO^3$.—Crystalline crusts, soluble in 2 pts. of water.

Iodate of Magnesium, $Mg(IO^3)^2.4H^2O$.—Shining crystals soluble in 3 pts. of boiling and 9·43 pts. of cold water. They are monoclinic, exhibiting the combination, ∞P . $\infty P\infty$. $+P$. $-P$. oP . $-\frac{1}{2}P\infty$. In the clinodiagonal principal section, ∞P : $\infty P = 78° 20'$; $+P$: $+P = 91° 53'$; $-P$: $-P = 120° 30'$; further, oP : $\infty P\infty = 100° 40'$; oP : $-\frac{1}{2}P\infty = 155° 32'$. The crystals cleave very distinctly parallel to $\infty P\infty$ (Marignac, Jahresber. 1857, p. 125). When heated they quickly become opaque and give off water, becoming completely anhydrous at 240° (Millon). At a red heat, the salt suffers decomposition and leaves pure magnesia.

Iodate of Manganese, $Mn(IO^3)^2$, is best obtained by precipitating a concentrated solution of acetate of manganese with iodate of sodium. It is pale red, soluble in 200 pts. of water, and when ignited leaves pure manganoso-manganic oxide. According to Berzelius, it contains 1 at. water $[Mn(IO^3)^2.H^2O]$.

Iodates of Mercury.—1. *Mercuric Iodate.* Produced by digesting recently precipitated mercuric oxide in iodic acid. It is a white anhydrous powder, insoluble in water, but dissolving easily in hydrochloric acid, with evolution of chlorine. The solution mixed with stannous chloride yields a red precipitate of mercuric iodide, which by the further action of the tin-salt is reduced to yellow mercuroso-mercuric iodide. Mercuric iodate when heated gives off oxygen and is converted into iodide.

2. *Mercurous Iodate*, $Hg^2(IO^3)^2$.—A solution of mercurous nitrate rendered as neutral as possible, yields with iodate of sodium a white precipitate, which is dissolved by hydrochloric acid, with evolution of chlorine, and yields a solution from which ammonia throws down iodide of nitrogen. It dissolves with difficulty in nitric acid, and is completely volatilised by heat, being at the same time resolved into mercuric iodide, mercury and oxygen.

Iodate of Nickel, $Ni(IO^3)^2.H^2O$.—Obtained by dissolving recently precipitated hydrate of nickel in iodic acid, or by evaporating to dryness a solution of 1 pt. sulphate of nickel and 1½ pt. iodate of sodium, and dissolving out the sulphate of sodium from the residue with water. From a hot-saturated solution, it separates as a light-green crystalline powder. It dissolves in 77½ pts. of boiling and 120⅝ pts. of cold water. When ignited, it leaves pure oxide of nickel. Ammonia dissolves it readily, forming a blue liquid, from which alcohol throws down blue crystals, or a crystalline powder, consisting of *iodate of nickel-diammonium*, $Ni(IO^3)^2.4NH^3 = I^2O^6.N^2\left\{\begin{matrix}N^2H^6Ni''\\ .\ H^6\end{matrix}\right.$.

Iodates of Potassium.—1. *Mono-iodate or Normal Iodate.* This salt is prepared: 1. By adding iodine to solution of potash till a brown colour is produced, evaporating to dryness, and dissolving out the iodide of potassium formed at the same time with alcohol of specific gravity 0·81:

$$6KHO + I^6 = KIO^3 + 5KI + 3H^2O.$$

Should the iodate thus obtained contain carbonate of potassium, the latter must be decomposed by acetic acid, the whole evaporated, and the acetate of potassium removed by alcohol.

2. By dissolving trichloride of iodine in potash, the products being iodate, iodide and chloride of potassium:

$$12KHO + 3ICl^3 = 2KIO^3 + 9KCl + KI + 6H^2O.$$

The iodide and chloride are dissolved out by alcohol, as in the former process, but the latter, being less soluble, is more difficult to remove.

3. By melting iodide of potassium in a crucible, leaving it to cool till it becomes semifluid, and then gradually adding 1½ pts. chlorate of potassium. The mass becomes fluid, swells up, and solidifies to a spongy mass of iodate and chloride of potassium. It is dissolved in hot water, the iodate left to crystallise, the crystals redissolved in hot water and the iodate precipitated by alcohol.

Mono-iodate of potassium forms small white cubic crystals (Gay-Lussac); $\infty O\infty$. ∞O (Marignac), but it is not easy to obtain distinct crystals. Specific gravity 3·979 (water at 17·5° = 1) (Kremers). It dissolves in 13 pts. water at 14° (Gay-Lussac); in 19·02 pts. water at 0·5°, in 14·85 pts. at 9·4°, in 10·77 pts. at 22·2°, in 5·95 pts. at 45·8°, and in 3·67 pts. at 69·2°. An aqueous solution of specific gravity 1·0741 at 19·5° contains 9·08 pts. KIO^3, for every 100 pts. water. The saturated aqueous solution boils at 102° (Kremers, Pogg. Ann. xciv. 271; xcv. 121; xcvii. 5). More soluble in aqueous iodide of potassium than in water. Insoluble in alcohol of specific gravity 0·81. Soluble in warm sulphuric acid without decomposition of the iodic acid. (Berzelius.)

At a low red heat, the salt melts and froths up, and is converted, with loss of

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22·59 per cent. oxygen into iodide of potassium (Gay-Lussac). If only part of the oxygen is expelled, the residue consists of iodide and iodate, without any periodate (Rammelsberg). It deflagrates with a purple light on glowing charcoal.

The aqueous solution exhibits with sulphydric acid and other reducing agents, the reactions already described for iodates in general (p. 301). From a solution of the salt mixed with iodide of potassium, the stronger acids precipitate iodine. With strong hydrochloric acid, it yields water, free chlorine, and chloride of iodine and potassium:

$$KIO^3 + 6HCl = 3H^2O + Cl^2 + KICl^4.$$

A solution of iodate of potassium in excess of boiling nitric acid yields crystals of iodic acid on cooling, while nitre remains in solution; if however it is evaporated to dryness, one half the nitre formed is decomposed, and there remains a mixture of 1 atom of nitrate and 1 atom of di-iodate of potassium. When greater heat is applied, all the nitric acid is decomposed into pernitric oxide and oxygen, and driven off, so that the residue consists merely of iodate of potassium. (Penny, Ann. Ch. Pharm. xxxvii. 203.)

Double-salt of Iodate and Acid Sulphate of Potassium, $KIO^3.KHSO^4$.—This salt separates after the tri-iodate (p. 305) from a solution of the mono-iodate mixed with sulphuric acid. It was first obtained by Serullas (Ann. Ch. Phys. [2] xliii. 113), who regarded it as a compound of the di-iodate with anhydrous di-sulphate of potassium. Millon (Ann. Ch. Phys. [3] ix. 497) supposed it to be a compound of mono-iodate and monosulphate of potassium, $2KIO^3.K^2SO^4$. The formula above given was determined by Marignac (Ann. Min. [5] ix. 1), who obtained it of the same composition, even when the proportions between the sulphuric acid, iodic acid and potash in the solution were varied. The crystals are monoclinic, exhibiting the combination $\infty P.\infty P2.\infty P3.\infty P\infty.oP.-P.-P2.-P\infty.+P\infty$ (predominating at the ends) $+3P\infty.(P\infty).(\frac{1}{2}P\infty)$. Angle $\infty P:\infty P$ in the clinodiagonal principal section = 54° 53′; $\infty P2:\infty P2$ in the same = 92° 10′; $oP:\infty P = 91° 29'$; $oP:\infty P\infty = 93° 14'$; $\infty P\infty:+P\infty = 115° 50'$; $\infty P\infty:-P\infty = 120° 42'$ (Marignac). When heated to redness, they give off oxygen and iodine and leave sulphate and iodide of potassium.

Di-iodate, $2KIO^3.I^2O^5$ or $K^2O.2I^2O^5$.—Obtained—1. By mixing the aqueous solution of the mono-iodate with hydrochloric acid, and precipitating with alcohol.—2. By partially saturating an aqueous solution of trichloride of iodine with caustic potash or carbonate of potassium, whereupon the mixture becomes heated, and on cooling deposits a compound of the di-iodate with chloride of potassium (the mother-liquor saturated with potash still yields the mono-iodate). The solution of this compound, largely diluted with water, and evaporated in the air at 25°, yields the di-iodate in beautiful transparent right rhombic prisms, with dihedral summits, having a sour, astringent taste, and acid reaction.

According to Marignac (Jahresb. 1856, p. 297), the crystals contain $K^2O.2I^2O^5.H^2O$, and exhibit three essentially different forms, one trimetric, the other two monoclinic, the occurrence of which is independent of the temperature of crystallisation. The trimetric crystals, which separate only from solutions containing a small quantity of the mono-iodate, exhibit chiefly the combination $\infty P.\infty\breve{P}\infty.\infty\bar{P}\infty.oP.\frac{1}{2}P.\frac{1}{3}\breve{P}\infty.\frac{1}{4}\bar{P}\infty$. Angle $\infty P:\infty P = 82° 10'$; P: P in the macrodiagonal principal section = 87° 10′; in the brachydiagonal = 101° 40′; $oP: P = 106° 4'$; $oP:\frac{1}{3}\breve{P}\infty = 127° 23'$; $oP:\frac{1}{4}\bar{P}\infty = 146° 48'$. No cleavage. According to Schabus (Jahresber. 1854, p. 310), the combination is oP (predominant) . $P.\frac{2}{3}P.\breve{P}\infty.\frac{1}{3}\breve{P}\infty.\infty P.\infty\breve{P}\infty.\infty\bar{P}\infty$. For P, the ratio of principal and secondary axes is 1 : 0·8973 : 0·7819. Angles P : P in the the terminal edges = 111° 13′ and 121° 2′; in the lateral edges = 97° 2′; $\infty P:\infty P = 82° 4'$. Cleavage imperfect parallel to oP.—The second form, which is monoclinic, separates, according to Marignac, chiefly from solutions containing a slight excess of acid. According to Schabus, the predominant combination is $\infty P2.\infty P\infty.oP.+P.-P$. The principal axis, clino- and ortho-diagonals, are in the proportion 1 : 1·7307 : 0·8627. Angle of the inclined axes = 87° 16′. $\infty P2:\infty P2$ in the clinodiagonal principal section = 78° 48′; $oP:-P = 129° 22'$; $oP:+P = 128° 9'$. The crystals are often joined as twins, the face of combination being apparently parallel to $+\frac{1}{4}P\infty$. Marignac has also measured these crystals, viewing them in a different direction, so that the faces oP, $\infty P\infty$, $\infty P2$, &c. in the preceding determination, become respectively $\infty P\infty$, oP, $(\frac{1}{2}P\infty)$, &c. in that of Marignac. Regarded thus, the crystals exhibit the faces $oP.\infty P\infty.\infty P2.-P.(P\infty).(\frac{1}{2}P\infty)$, with several subordinate clinodiagonal domes and hemipyramids. $\infty P2:\infty P2$ in the clinodiagonal principal section = 120° 17′; $-P:-P$ in the same = 87° 48′; $oP:(P\infty) = 110° 53'$; $oP:(\frac{1}{2}P\infty) = 127° 20'$; $oP:\infty P\infty = 91° 56'$. The crystals are almost always intersecting twins, with the face of combination $-P\infty$; rarely contact-twins joined by the face oP. Cleavage parallel to oP.—The third form, which accompanies the other two, is also monoclinic,

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and exhibiting the combination oP . ∞P . +P∞.
Angle ∞P : ∞P in the clinodiagonal principal
°; oP : ∞P = 96° 40′; oP : −P∞ = 129° 28′;
Rammelsberg, who formerly regarded the crystals
ination (Jahresb. 1857, p. 125), that they contain
.

in 75 pts. water at 15°, insoluble in alcohol
off oxygen and vapour of iodine, and is converted,
odide. It deflagrates on glowing charcoal.
te and chloride of potassium, $2KCl.2KIO^3.I^2O^5$, is
f trichloride of iodine is not quite saturated with
porate:

$$(2KCl.2KIO^3.I^2O^5) + 4ICl + 18HCl;$$

m with dilute hydrochloric acid:

$$(2KCl.2KIO^3.I^2O^5) + H^2O.$$

and elongated four-sided tables with truncated
n. Phys. [2] xliii. 121). According to Millon
Jahresb. 1856, p. 298) the crystals contain 1 at.
rg (Pogg. Ann. xcvii. 92), who also finds them to
ibiting the combination ∞P . ∞P∞ . ∞P̆∞ . P̆∞ .
the macrodiagonal principal section = 82° 8′;
∞ : ½P̆∞, in the same = 132° 16′. Proportion of
principal axis = 0·8713 : 1 : 0·7709. The crystals
er at 15° (Serullas). Cold alcohol dissolves out
e di-iodate. (Filhol, J. Pharm. xxv. 506.)
otassium, $K^2S^2O^7.K^2I^2O^{11}$?—This, according to
louble salt obtained, after the separation of the
nono-iodate is mixed with sulphuric acid. But,
his salt contains, not the di-iodate, but the mono-

I^2O^5.—This salt is obtained by mixing aqueous
potash, or by adding a solution of the mono- or
horic, hydrochloric, nitric, or silicic acid. When
ted with a large excess of dilute sulphuric acid,
ri-iodate crystallises out, leaving in solution a
e of potassium.
ent crystals—triclinic, according to Rammelsberg
ee from sulphuric acid, assume a reddish colour
and Rammelsberg, they are anhydrous; according
in 2 at. water: $K^2O.3I^2O^5.2H^2O$. The salt when
ing iodide of potassium. It dissolves in 25 pts.
Phys. [2] xliii. 117.)
Lussac, a solution of the mono-iodate mixed with
xcess of potash; but, according to Rammelsberg,
ses out.
ned by precipitating nitrate of silver with iodic
soluble in water, nearly insoluble in dilute nitric
olution yielding by spontaneous evaporation, pure
s, which, according to Marignac (Ann. Min. [5]
inclined to one another at an angle of 127½°, and
of the prism, extending in a direction parallel to
passed into the solution of the salt in ammonia,
throws down iodide of silver. Hydrochloric acid
de of silver, chloride of iodine, and free chlorine.
o-iodate, $NaIO^3$ or $Na^2O.I^2O^5$, is obtained: 1. By
rough 10 pts. of water containing 1 pt. of iodine
liquid with carbonate of sodium; passing chlorine
the iodine thus thrown down; again neutralising
iodine thus separated by means of chlorine, and
ed to $\frac{1}{10}$th its bulk, mixed, while still warm, with
ompact crystalline mass, consisting of eight-sided
d from adhering chloride of sodium by washing
iv. 362). An excess of carbonate of sodium must
date of sodium will be formed (Magnus and
uflos (Schw. J. lxii. 390), the addition of alcohol
date can be separated from the chloride of sodium

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by crystallisation.—2. By partially saturating aqueous trichloride of iodine with caustic soda or carbonate of sodium, precipitating with alcohol, washing the precipitate with the same liquid, and recrystallising from hot water. (Serullas.)

Mono-iodate of sodium separates from an aqueous solution left to evaporate in moderately warm air (Rammelsberg), or from a hot concentrated solution on cooling (Penny), in crystals containing 1 at. water: $NaIO^3.H^2O$. This hydrate forms tufts of fine silky needles, which, if the temperature falls below 5°, while they are still immersed in the liquid, are converted into the pentahydrated crystals. They give off all their water at 180° (Rammelsberg, Penny). The pentahydrated salt, $NaIO^3.5H^2O$, obtained by spontaneous evaporation below 5°, forms octagonal prisms of the trimetric system, with pyramidal summits, the combination being $\infty\breve{P}\infty . \infty\breve{P}\infty . P$, with $\breve{P}\infty$ subordinate. Axes $a : b : c = 0{\cdot}9534 : 1 : 0{\cdot}6607$ (ii. 144). Angles P : P in the terminal edges = 119° 56′ and 123° 30′; in the lateral edges = 87° 30′; $\infty P : \infty P = 92° 45'$ and 87° 15′. The crystals are prismatically elongated in the direction of the principal axis, the faces ∞P being almost always unequally developed. When exposed to the air, they give off 4 at. water and are converted into the monohydrated salt (Rammelsberg, Pogg. Ann. xliv. 548; xc. 12). According to Millon (Ann. Ch. Phys. [3] ix. 400), crystals containing 2, 3, 6, and 8 at. water are also obtained, under special circumstances. Penny (Ann. Ch. Pharm. xxxvii. 203), by cooling a somewhat dilute solution, obtained crystals containing $NaIO^3.3H^2O$.

The anhydrous salt, obtained by drying the crystals at 150°, dissolves in 13·8 pts. of water at 14·5°, but is insoluble in alcohol (Gay-Lussac). According to Kremers (Pogg. Ann. xcvii. 5, 8), it dissolves in 39·75 pts. water at 0°, in 11·03 pts. at 20°, in 6·95 pts. at 40°, in 4·79 pts. at 60°, in 3·61 pts. at 80°, and in 2·95 pts. at 100°. The saturated solution boils at 102°. A solution of specific gravity 1·0698 at 19·5° contains 8·13 pts. of the anhydrous salt for every 100 pts. of water. (Kremers, Pogg. Ann. xcix. 444.)

Mono-iodate of sodium melts when heated, and while still below redness, gives off 24·45 per cent. oxygen, together with iodine, leaving a mixture of iodide of sodium and soda (Gay-Lussac). According to Liebig, it leaves a hypo-iodite of sodium, containing $2Na^2O.I^2O$ or $Na^4I^2O^3$; when heated to redness, it yields 24·21 per cent. of oxygen, and 75·79 of iodide of sodium (Benckiser). It detonates on glowing charcoal, and slightly when mixed with sulphur and struck (Gay-Lussac). It is decomposed by concentrated hydrochloric acid into water, chlorine, and a yellow liquid, which probably contains trichloride of iodine and sodium, $NaCl.ICl^3$, but does not yield this compound in a crystalline form (Filhol, J. Pharm. xxv. 440). Heated with a little nitric acid, it yields di-iodate, and with a larger proportion, tri-iodate of sodium in the anhydrous state (Penny). When dissolved hot in a mixture of equal quantities of sulphuric acid and water, it gives, by evaporation, crystals which, when placed on bibulous paper and nearly dry, become all at once fluid and tenacious. (Liebig.)

Double Salts of Mono-iodate of Sodium.—1. With *bromide of sodium*, $2NaBr.NaIO^3.9H^2O$. —Obtained by dissolving the iodate in a hot strong solution of bromide of sodium. It crystallises, by cooling or spontaneous evaporation, in aggregations of extremely fine, colourless, transparent, six-sided laminæ, apparently rhombohedral combinations. It is easily soluble in water. When heated, it gives off a large quantity of water, melts, gives off oxygen mixed with iodine, and leaves a mixture of bromide and iodide of sodium. Two-thirds of the water is given off over sulphuric acid. (Rammelsberg, J. pr. Chem. lxxxv. 436; Rép. Chim. pure, 1862, p. 251.)

2. *With Chloride of Sodium*, $3NaCl.2NaIO^3.9H^2O$.—(1.) When chlorine is passed through a solution of iodate of sodium mixed with a rather large quantity of caustic soda as long as basic periodate of sodium (p. 310) continues to separate, the decanted liquid, when left at rest, deposits crystals of chloride of sodium, first combined with iodate of sodium, then by itself, and afterwards mixed with chlorate of sodium.—(2.) The mother-liquor obtained in the second mode of preparing mono-iodate of sodium (see above) deposits, at a higher temperature and greater degree of concentration, crystals of the compound of iodate and chloride. The crystals, which are large, colourless, and often transparent, belong to the triclinic system, and are sometimes triclinic pyramids having all their edges and summits truncated, frequently, also, modified by various pyramidal faces. They also form twins joined by the basal end-faces, and giving the crystal a tabular character. The axes *a*, *b*, *c* of the pyramid (*c* being the principal axis) are to one another as 1·1309 : 1 : 1·10436. The inclinations of the principal sections are by direct measurement, $\infty\breve{P}\infty : \infty\breve{P}\infty = 97° 16'$; $oP : \infty\breve{P}\infty = 104° 0'$; $oP : \infty\breve{P}\infty = 100° 63'$. Inclinations of the axes, by calculation, $b : c = 102° 57'$; $a : c = 99° 9'$; $a : b = 94° 56'$. The crystals are not efflorescent, but when heated, they give off their water, and melt to a clear liquid which gives off nothing but oxygen gas, and when very strongly heated, leaves a mixture of iodide and chloride of sodium. Water extracts the chloride of sodium, leaving the iodate with 1 at. water. (Rammelsberg, Pogg. Ann. xliv. 548: cxv. 584.)

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3. *With Iodide of Sodium*, $NaI.NaIO^3.10H^2O$ (Mitscherlich); $3NaI.2NaIO^4.19H^2O$ (Penny); $3NaI.2NaIO^3.20H^2O$ (Marignac).—This compound, discovered by Mitscherlich (Pogg. Ann. xi. 162; xvii. 481), is obtained by dissolving iodine in a cold and not very concentrated aqueous solution of caustic soda (or the carbonate, according to Penny) till it begins to turn brown, then leaving it in a cold place till it crystallises. Prisms of pure iodate of sodium then first appear, but afterwards redissolve, and are replaced by this compound (Mitscherlich). The same crystals are produced in a few days by immersing crystals of iodate of sodium in a strong solution of the iodide, and leaving the liquid to itself at a temperature not above 15° (Penny, Ann. Ch. Pharm. xxxvii. 202). The crystals are hexagonal tables, oR . ∞R, with + R, − ½R and other faces. Angle oR : R = 115° 7′; oR : − ½R = 133° 10′ (Marignac, Jahresb. 1857, p. 124). When heated they first give off water, then oxygen, with a trace of iodine. Cold water dissolves them without decomposition, but alcohol dissolves the iodide of sodium, leaving the iodate.

Acid Iodates of Sodium.—When an aqueous solution of trichloride of iodine is mixed, first with mono-iodate of sodium, then with alcohol, the di-iodate separates out, but this salt, if dissolved in water and evaporated, yields crystals of the mono-iodate, and an acid mother-liquor (Serullas, Ann. Ch. Phys. xlv. 59). By evaporating also a mixture of the iodate with excess of iodic acid, the neutral salt crystallises out first, and then the iodic acid (Rammelsberg). Penny obtained a di-acid and tri-acid salt, by treating the mono-iodate with nitric acid.

Iodate of Tin.—Iodate of sodium forms, with dichloride of tin, a precipitate which is white at first, but soon turns yellow, brown and grey, yielding tetrachloride and di-oxide of tin and free iodine.

Iodates of Uranium.—The *uranic salt*, $U^2O^3.I^2O^5.5H^2O$ or $(U^2O^2)''(IO^3)^2.5H^2O$, is obtained, by double decomposition, as a yellow precipitate which dissolves with difficulty in nitric acid, leaves uranoso-uranic oxide when ignited, and is decomposed by potash. *Uranous iodate* is obtained by precipitation from uranous chloride, as a greyish-green substance, which soon decomposes, being partially converted into the uranic salt.

Iodate of Yttrium.—Precipitable from concentrated solutions; remains as a crystalline crust on evaporation. It is anhydrous, dissolves in 160 pts. water, and when suddenly heated, decomposes with explosion and deflagration.

Iodate of Zinc, $Zn(IO^3)^2.2H^2O$.—To prepare this salt, a solution of sulphate of zinc and iodate of sodium in equivalent proportions is evaporated to dryness, and the resulting sulphate of sodium is dissolved out by water. Iodate of zinc then remains as a white powder, soluble in 75·9 pts. of hot, and 113·8 pts. of cold water, soluble also in nitric acid and in ammonia. The ammoniacal solution yields by spontaneous evaporation, or on addition of alcohol, a crystalline salt consisting of $3Zn(IO^3)^2.8NH^3$ or $3(N^2H^6Zn)(IO^3)^2.2NH^3$. It is decomposed by water, with separation of oxide of zinc.

Iodate of zinc leaves oxide of zinc when ignited.

Periodic Acid, Anhydride and Salts.

Periodic or **Hyperiodic acid.** HIO^4 or $H^2O.I^2O^7$, or according to Langlois, H^3IO^5 or $5H^2O.I^2O^7$. (Magnus and Ammermüller, Pogg. Ann. xxviii. 514.—Benckiser, Ann. Ch. Pharm. xvii. 254.—Langlois, Ann. Ch. Phys. [3] xxxiv. 257; Jahresb. 1852, p. 345.)—This acid, which was discovered by Magnus and Ammermüller (Pogg. Ann. xxviii. 514), is produced, in the form of a disodic salt, by the action of chlorine on a solution of iodate of sodium mixed with carbonate of sodium or caustic soda:

$$\underset{\text{Sodic iodate.}}{NaIO^3} + 3NaHO + Cl^2 = \underset{\text{Disodic periodate.}}{Na^2H^3IO^6} + 2NaCl.$$

A good method of preparing it is to add 1 pt. of iodine to a solution of 7 pts. carbonate of sodium in 100 pts. water, and pass chlorine into the heated liquid as long as a precipitate continues to form. This precipitate, which consists of disodic periodate, is dissolved in nitric acid perfectly free from nitrous acid; nitrate of silver is then added; the resulting yellow precipitate of diargentic periodate is dissolved in hot dilute nitric acid; and the solution is concentrated at a moderate heat, till the monargentic periodate, $AgIO^4$, crystallises out; this salt, separated from the mother-liquor, is treated with cold water, which extracts half the periodic acid, reproducing the diargentic periodate; and the filtered solution is evaporated: pure periodic acid then crystallises out (Magnus and Ammermüller). Another method is to precipitate the solution of the disodic salt in nitric acid with nitrate of lead, decompose the precipitate of per-

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iodate of lead with somewhat less than an equivalent quantity of dilute sulphuric acid, and concentrate the filtrate by evaporation (Benckiser). According to Langlois, however, the acid thus obtained is always contaminated with iodic acid.

The acid may likewise be obtained by igniting iodate of barium, which then gives off iodine and oxygen, and is converted into pentabasic periodate of barium—and decomposing that salt with sulphuric acid. But this method is not advantageous, because a considerable portion of the iodic acid is completely resolved by the heat into iodine and oxygen.

The iodates of the alkali-metals give off the whole of their oxygen when heated, and are converted into iodides; consequently periodic acid cannot be prepared in the same manner as perchloric acid (i. 910).

Periodic acid separates from its aqueous solution by evaporation, at a gentle heat, in colourless crystals, apparently having the form of oblique rhombic prisms, which deliquesce quickly in moist air, melt at 130°, and at 160° give off their water, leaving a white mass of periodic anhydride, I^2O^7, which, at 180° or 190°, gives off oxygen with great rapidity, leaving iodic anhydride (Benckiser). The crystals are rhombic prisms, having the composition $H^5IO^6 = HIO^4.2H^2O$ or $5H^2O.I^2O^7$. They melt at 130°, and between 200° and 210°, give off 5 at. water and 2 at. oxygen, and are reduced to iodic anhydride, I^2O^5, which at a higher temperature is completely resolved into iodine and oxygen. (Langlois.)

Periodic acid dissolves very easily in *water*, sparingly in *alcohol* and in *ether*, in which solutions it is slowly reduced to iodic acid. It is likewise reduced by many other *organic substances*, and instantly by *hydrochloric*, *sulphurous*, or *sulphydric acid*. With hydrochloric acid it forms water, chloride of iodine, and free chlorine. *Sulphur* is not oxidised by it; but *phosphorus* is partly converted into phosphoric acid—for the most part, however, into oxide of phosphorus. *Metals* are oxidised by the solution, forming basic periodates. It forms a precipitate with *tannic acid*, a reaction which distinguishes it from iodic acid. The precipitate dissolves in potash and in ammonia, with dark red colour, arising from the oxidation of the tannic acid, the iodine at the same time uniting with the alkali-metal. (Langlois.)

Periodates.—Periodic acid is generally regarded as monobasic, like perchloric acid, the formula of its normal salts being MIO^4 or $M^2O.I^2O^7$. Only four of these anhydrous monometallic periodates are however known, namely those of ammonium, potassium, sodium, and silver. All other periodates contain a larger proportion of base, and may be derived from the crystallised acid H^5IO^6, regarded as $HIO^4.2H^2O$, by the replacement of the water of crystallisation by a metallic oxide or hydrate, thus:

HIO^4	.	H^2O	. H^2O . .	Periodic acid.
$(NH^4)IO^4$	.	H^2O	. H^2O . .	Mono-ammonic periodate.
$NaIO^4$	.	NaHO.	H^2O . .	Disodic periodate.
$PbIO^4$	.	Pb^2O .	H^2O . .	Triplumbic periodate.
$CuIO^4$	.	Cu^2O .	CuHO. .	Tetracupric periodate.
$BaIO^4$	.	Ba^2O .	Ba^2O . .	Pentabarytic periodate.

The existence of the monohydric acid HIO^4 must however for the present be regarded as hypothetical, the only hydrate whose constitution has been established by analysis being the pentahydric acid, H^5IO^6, analysed by Langlois; and from this, regarded as a pentatomic molecule, $\left.\begin{matrix}(IO)^{vii}\\ H^5\end{matrix}\right\}O^5$, the greater number of the periodates may be derived by the partial or total replacement of the hydrogen by metals. The anhydrous periodates of potassium, silver, and sodium, (MIO^4) may then be regarded as metaperiodates, bearing to the orthoperiodates, M^5IO^6, a relation similar to that of metaphosphoric to orthophosphoric acid. There are a few periodates which cannot be included in either of the preceding formulæ, viz. a barium-salt containing $5BaO.2I^2O^7$ or $3BaO.2BaI^2O^8$, a potassium-salt containing $2K^2O.I^2O^7$ or $K^2O.2KIO^4$, and a silver-salt containing $2Ag^2O.H^2O.I^2O^7$ or $Ag^2O.HIO^4$.

The monometallic periodates are resolved by heat into oxygen and metallic iodide; the polymetallic salts into a mixture of iodide and oxide or reduced metal. Most periodates are sparingly soluble or insoluble in water, but they all dissolve easily in dilute nitric acid. The solution of the monosodic salt, added to a solution of a barium-, calcium-, lead-, or silver-salt, precipitates the polymetallic or basic periodates of these bases, the liquid acquiring an acid reaction.

Periodate of Ammonium, $(NH^4)IO^4.2H^2O$, separates on mixing the solutions of ammonia and periodic acid. It dissolves in a large quantity of water, and the solution, evaporated at a gentle heat, yields crystals, apparently having the form of rhombic prisms. It has an acid reaction, and explodes when heated in a tube. (Langlois.)

Periodates of Barium.—The monobarytic salt is not known. A *pentabarytic* or

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pentabasic salt, $Ba^5I^2O^{12}$ or $5BaO.I^2O^7$, is obtained by igniting iodate of barium or a mixture of iodide and peroxide of barium, and dissolving out the iodide of barium from the residue with water. Its solution in nitric acid yields with nitrate of silver a yellow-brown precipitate of basic periodate of silver. (Rammelsberg, Pogg. Ann. xliv. 272.)

A salt containing half as much base as the last, viz. $Ba^5(IO^6)^2.I^2O^7$ or $5BaO.2I^2O^7$, is precipitated by ammonia from the solution of the pentabasic salt, or from a mixture of a soluble barium-salt with monobasic periodate of sodium dissolved in nitric acid; also on mixing nitrate of barium with dibasic periodate of sodium. The precipitate contains 5 at. water, which are given off at 100°; by longer exposure to this temperature, the salt is completely converted into iodate of barium. (Rammelsberg.)

A *dibarytic* or *dibasic* salt, BaH^2IO^6 or $2BaO.3H^2O.I^2O^7$, is obtained by adding baryta-water to a solution of the corresponding sodium-salt mixed with a few drops of nitric acid. It is a white precipitate which decomposes at a red heat, yielding the pentabarytic salt (Langlois):

$$10BaH^2IO^6 = 2Ba^5(IO^6)^2 + I^6 + O^{21} + 15H^2O.$$

Periodates of Calcium.—A *dicalcic salt*, CaH^2IO^6 or $2CaO.3H^2O.I^2O^7$ (at 100°), is obtained by decomposing the sodium salt, NaH^2IO^6, with nitrate of calcium, as a white precipitate, which appears crystalline under the microscope, and when heated gives off water, oxygen, and iodine, and leaves the pentacalcic salt, $Ca^5I^2O^{12}$ (Langlois). The latter is likewise obtained, but mixed with lime, by igniting iodate of calcium in a close vessel.

Periodate of Copper, Cu^2HIO^6 or $4CuO.H^2O.I^2O^7$, is precipitated by mixing the solutions of sulphate of copper and the monosodic salt—a considerable quantity, however, remaining in solution—or by the action of aqueous periodic acid in slight excess of hydrated carbonate of copper. (Langlois.)

Periodates of Iron.—Iron-salts (ferrous or ferric) form, with solution of periodate of sodium, yellowish white precipitates, easily soluble in nitric acid (Benckiser). According to Langlois, periodic acid, in contact with ferrous oxide, is reduced to iodic acid, and ferric iodate separates out. Similar reaction with manganous oxide.

Periodates of Lead.—A *triplumbic* or *tribasic salt*, $Pb^3H^4(IO^6)^2$ or $3PbO.2H^2O.I^2O^7$, is precipitated on mixing 1 at. of the disodic salt with 3 at. nitrate of lead, in microscopic crystals, which do not suffer any loss of weight between 120° and 130°, but, at a higher temperature, give off water, oxygen, and iodine, and leave an oxyiodide of lead containing $PbI^2.5PbO$ (Langlois):

$$2Pb^3H^4(IO^6)^2 = PbI^2.5PbO + O^{15} + I^2 + 4H^2O.$$

Periodate of Lithium, Li^2IO^6?—By treating carbonate of lithium with periodic acid and evaporating the solution at a gentle heat, a crystalline mass is obtained, which dissolves completely in water, and when dried in a vacuum, and then heated to redness, gives off successively water, oxygen, and iodine, but without undergoing complete decomposition. (Langlois.)

Periodate of Magnesium.—Magnesium-salts are not precipitated by solution of periodate of sodium. Carbonate of magnesium, immersed in aqueous periodic acid, is converted into insoluble periodate of magnesium, which dissolves, however, in excess of the acid. The salt consists of small prismatic crystals, which, when dried at mean temperatures, contain $2MgH^2IO^6.9H^2O$ or $2MgO.3H^2O.I^2O^7 + 9$ aq., give off 9 at. water, at 100°, and leave pure magnesia when ignited. (Langlois.)

Periodates of Potassium.—The *monopotassic salt*, KIO^4, is precipitated in sparingly soluble crystalline grains on passing chlorine into a solution of the iodate mixed with potash or carbonate of potassium. Its aqueous solution, mixed with caustic potash, yields the *tetrapotassic salt*, $K^2O.2KIO^4$ or $2K^2O.I^2O^7$, which is also sparingly soluble in water, and is converted by ignition into a mixture of potash and iodide of potassium. The neutral salt when ignited leaves the pure iodide. (Magnus and Ammermüller.)

Periodates of Silver.—Nitrate of silver added to a solution of disodic periodate, throws down a greenish yellow precipitate, which is a basic periodate of silver. By washing it with water containing nitric acid, then dissolving it nearly to saturation in warm nitric acid, and evaporating by heat, the *monoargentic salt*, $AgIO^4$, is obtained in anhydrous orange-yellow crystals. This salt is decomposed by warm water, which dissolves out half the acid, leaving a blackish-brown residue of the *tetrargentic salt*, $2Ag^2O.I^2O^7.H^2O$ or $Ag^8O.2AgIO^4.H^2O$, which turns red by trituration. Cold water decomposes the salt in like manner, but the residual salt is a yellow powder, consisting of $Ag^2H^3IO^6$ or $2Ag^2O.3H^2O.I^2O^7$, and separates from a solution in dilute slightly warmed nitric acid, in straw-yellow crystals, which, according to Rammelsberg

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(Jahresb. 1857, p. 125), are rhombohedral, exhibiting the combination R . −½R . oR. For R, the ratio of the secondary axes to the principal axis = 1 : 2·0653. Angle R : R in the terminal edges = 74° 0′; oR : R = 112° 45′. The crystals become darker-coloured by exposure to light. On pouring boiling water on these crystals or on the yellow powder, 2 atoms of water are removed, and the red salt above mentioned is produced. (Magnus and Ammermüller.)

Periodates of Sodium.—The *monosodic* salt, $NaIO^4$, is obtained by saturating the disodic salt with periodic acid, and evaporating. It is colourless, very soluble in water, anhydrous, crystallises readily, and is permanent in the air (Magnus and Ammermüller). The crystals are dimetric, P . P∞. For P, the ratio of the secondary axes to the principal axis is 1 : 1·59. Angle P : P in the terminal edges = 99° 30′; in the lateral edges = 132° 4′. The crystals are colourless. (Rammelsberg, *loc. cit.*)

The *disodic* or *dibasic* salt, $Na^2H^3IO^6$ or $2Na^2O.3H^2O.I^2O^7$, is obtained by passing chlorine gas into a hot solution of 1 pt. iodine and 7 pts. carbonate of sodium in 100 pts. water, or into a solution of 1 pt. iodate of sodium mixed with 3 pts. of caustic soda (Magnus and Ammermüller). Langlois uses equal weights of caustic soda and the iodate, and to obtain a solution as concentrated as possible, first dissolves the caustic soda in water, then adds the iodate, and surrounds the filtered solution with hot water while the chlorine is passing into it; the sodic periodate then separates in considerable quantity, as a crystalline powder, having the composition just mentioned. It is sparingly soluble in cold water, somewhat more in warm water, and may be obtained in the crystalline form from a boiling solution of the neutral salt mixed with caustic soda. At a white heat, it gives off 3 at. water and 8 at. oxygen, and leaves an oxyiodide of sodium:

$$2Na^2H^3IO^6 - 3H^2O - O^8 = Na^4I^2O.$$

At a low red heat, it loses only 3 at. oxygen, leaving a residue of *hypo-iodite of* sodium, $Na^4I^2O^3 = 2Na^2O.I^2O$ (or perhaps a compound of iodide and *iodite* of sodium, 2NaI + $3Na^2O.I^2O^3$ or $NaI.Na^2O.NaIO^2$). This compound is sparingly soluble in water, has an alkaline reaction, and bleaches vegetable colours, but loses this property when boiled with water, iodate of sodium being then formed, and the salt becoming easily soluble. On exposure to the air it turns moist, and gradually yields free iodine.

Periodate of Zinc.—Hydrated carbonate of zinc is converted by aqueous periodic acid into a granular powder of periodate of zinc, Zn^2HIO^6 or $4ZnO.H^2O.I^2O^7$, which dissolves readily in excess of the acid, forming a solution, which, when evaporated at a gentle heat, yields laminar crystals of another salt containing $3ZnO.7H^2O.2I^2O^7$, *i.e.* a double per-iodic molecule, $Zn^3H^{14}I^4O^{24} = \left.\begin{matrix}(\overline{IO})^4\\ Zn^3H^{14}\end{matrix}\right\}O^{20}$. (Langlois.)

IODINE, SELENIDE, SULPHIDE, and **TELLURIDE OF.** See Selenium, Sulphur, and Tellurium, Iodides of.

IODITE, IODOPYRITE, IODIC SILVER. Native iodide of silver. (See Silver, Iodide of.)

IODOBENZOIC ACID. $C^7H^5IO^2$.—An acid produced by the action of hydriodic acid on diazobenzo-oxybenzamic acid:

$$\underset{\text{Diazobenzo-oxybenzamic acid.}}{C^{14}H^{11}N^3O^4} + 2HI = \underset{\text{Hydriodate of oxybenzamic acid.}}{C^7H^7NO^2.HI} + \underset{\text{Iodobenzoic acid.}}{C^7H^5IO^2} + N^2.$$

It crystallises in needles, is heavier than water, easily soluble in alcohol; sublimes without decomposition; forms a white silver-salt, $C^7H^4AgIO^2$, insoluble in water and in alcohol; is converted by fuming nitric acid into nitro-iodobenzoic acid. (Griess, Ann. Ch. Pharm. cxiii. 201.)

IODOBRUCINE. Syn. with Iodide of Brucine. (See Brucine, i. 683.)

IODO-CAOUTCHIN. See Caoutchin (i. 737).

IODO-CHLORO-NITROHARMINE. Syn. with Di-iodide of Chloro-nitro-harmine. (See Harmine, iii. 12).

IODOCINCHONINE. See Cinchonine (i. 979).

IODOCINNAMIC ACID. $C^9H^7IO^2$?—When cinnamic acid is melted with excess of iodine, and the dark brown mass is boiled with water till all the free iodine is volatilised, the liquid on cooling yields small colourless stellate crystals of iodocinnamic acid, which acquire a faint yellow colour on exposure to the air. The acid dissolves easily in hot water and in alcohol. (Herzog, N. Br. Arch. xx. 147.)

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IODOCODEÏNE. Syn. with Iodide of Codeïne. (See CODEÏNE, i. 1068).

IODOFORM. CHI^3. *Di-iodated iodide of methyl.* (Gm. vii. 330; Gerh. i. 609.) —This compound, which was discovered in 1824 by Serullas (Ann. Ch. Phys. xxv. 314), is produced by the action of iodine and alkalis or alkaline carbonates on wood-spirit, alcohol, or ether; in small quantity also by the action of the same substances on cane-sugar, glucose, gum, dextrin, and several albuminous substances. It has also been observed among the products obtained by heating glycerin with hydriodic acid. (Erlenmeyer, Jahresb. 1861, p. 668.)

Preparation.—1 pt. of alcohol is added to a solution of 2 pts. crystallised carbonate of sodium in 10 pts. water; the liquid is heated to 60 or 80°; and 1 pt. of iodine is added by small portions, till it is entirely dissolved, and the liquid has become colourless. Iodoform then makes its appearance towards the end of the operation and sinks to the bottom of the hot liquid, which must be filtered to collect this first portion of the product. The mother-liquor is then again heated to 60° or 80°; another portion of carbonate of sodium, equal to the former, is dissolved in it; a fresh portion of alcohol is added; and a current of chlorine is passed into the liquid, which must be continually agitated, so that the iodine which separates may mix well with it. When the process is so conducted that a slight excess of iodine is constantly present, iodoform is produced in abundance. When a considerable quantity has been deposited, the stream of chlorine is interrupted, the liquid is left to decolorise, and the second portion of iodoform is added to the first. The mother-liquor may then be treated with chlorine and a third portion of iodoform obtained. The process, when properly conducted, yields a quantity of iodoform weighing 40 or 50 per cent. of the iodine used. Care must be taken, throughout the operation, to avoid a great excess of iodine, as in that case the iodoform will not be produced at all. Borax may be used instead of carbonate of sodium, and will yield a product of equal amount. With phosphate of sodium the product is not so good. (Filhol, J. Pharm. [3] vii. 267.)

Cornelius and Gille (*ibid.* xxii. 196) prepare iodoform by adding hypochlorite of calcium to an alcoholic solution of iodide of potassium heated to 40°, continuing the addition till the liquid becomes colourless. It then on cooling yields a crystalline deposit, consisting of iodoform mixed with iodate of calcium, from which the iodoform may be dissolved by boiling alcohol. 8 pts. of iodide of potassium yield, by this process, 2 pts. of iodoform and 2 pts. of iodate of calcium.

Properties.—Iodoform crystallises in nacreous scales, friable, soft to the touch, having a sulphur-yellow colour and the odour of saffron. According to Rammelsberg and Kokscharow (Jahresber. 1857, p. 431), the crystals are hexagonal combinations oP . P. For P the ratio of the secondary axes to the principal axis is 0·9025 : 1. Angle P : P in the terminal edges = 133° 36′; in the lateral edges = 104°. Specific gravity about 2·0. Melts between 115° and 120°, and then vaporises, partly without alteration, partly resolved into iodine and hydriodic acid, with a residue of charcoal. With vapour of water it distils undecomposed. It is not perceptibly soluble in *water*, *acids*, or aqueous *alkalis*, but dissolves readily in *alcohol*, *ether*, and *oils*, both fixed and volatile.

Decompositions.—1. Iodoform heated in a sealed tube to 150°, either alone or with *iodine*, is resolved into di-iodide of methylene, and a number of brown substances not yet examined (Hofmann, Chem. Soc. J. xiii. 65).—2. Iodoform is acted upon by *bromine*, yielding bromiodoform, $CHBrI^2$.—3. With moist *chlorine*, it yields chlorocarbonic oxide, hydrochloric acid, and protochloride of iodine:

$$CHI^3 + H^2O + Cl^2 = COCl^2 + 3HCl + 3ICl.$$

—4. Heated with *pentachloride of phosphorus*, it yields an oily liquid, perhaps chloroform, or according to Butlerow, di-iodide of methylene, CH^2I^2.—5. Distilled with *chloride of mercury*, *lead*, or *tin*, it yields chloriodoform, $CHCl^2I$.—6. Distilled with *sulphide of mercury*, it yields a small quantity of an oily liquid, which, according to Bouchardat (J. Pharm. xxiii. 12) is sulphoform, C^2HS^3; but according to Eggert (Chem. Centr. 1857, p. 513) is nothing but disulphide of carbon.—7. With *cyanide of mercury* or *cyanide of silver* it yields a sublimate of iodide of cyanogen.—8. When *cyanogen gas* is passed into an alcoholic solution of iodoform, the liquid becomes heated and assumes a violet tint; and if then left at rest, deposits golden-yellow, prismatic crystals, from which alcohol extracts two substances having a strong metallic lustre; one with a greenish gold, the other with a violet colour; the latter appears to be *cyanide of di-iodomethyl*, $CHI^2.Cy$ (St.-Evre, Compt. rend. xxvii. 533).—9. Heated with alcoholic solution of *sulphocyanate of potassium* to 100° in sealed tubes, it yields a gas and oily compound which has an odour of horse-radish, and forms a crystalline compound with ammonia, though not so readily as oil of mustard (Hlasiwetz, Ann. Ch. Pharm. cxii. 184).—10. *Mercuric oxide* gently heated with iodoform acts energetically upon it, producing

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water, carbonic anhydride, formic acid, and mercuric iodide.—11. Iodo with *aqueous potash* is partly converted into formate and iodide of potassiu however, volatilising with the watery vapour.—12. With *alcoholic potas* liquid which Brüning, who first obtained it (Ann. Ch. Pharm. civ. 187) C^2HI^3O, but which, according to Butlerow, is di-iodide of methylene. *ethylate of sodium*, iodoform yields iodide of methylene, CH^2I^2, together w sodium and aldehyde (Butlerow, Ann. Ch. Pharm. cvii. 110):

$$C^2H^5NaO + CHI^3 = CH^2I^2 + NaI + C^2H^4O.$$

According to more recent experiments by Butlerow (*ibid.* cxiv. 204; c appears that acrylic acid, $C^3H^4O^2$, and ethyl-lactic acid, $C^5H^{10}O^3$, are like in this reaction.

14. Iodoform heated with *potassium* produces a violent explosion.

15. With *triethyl-phosphine*, iodoform unites directly, without the aid of h the tri-iodide of formyl-nonethyl-triphosphonium (Hofmann, Proc. Roy. S

$$CHI^3 + 3(C^2H^5)^3P = C^{19}H^{46}P^3I^3 = [(CH)'''(C^2H^5)^9P^3]'''$$

IODOLITE. A meteoric mineral mentioned by C. U. Shepard amo of others which have been but imperfectly described. (Sill. Am. J. [2] 402; xv. 363.)

IODOMECONE. $C^9H^4I^2O^3$. (J. Brown, Edinb. Phil. Trans. xxi. substance formed by treating pyromeconic acid with excess of prot iodine:

$$C^5H^4O^3 + 8ICl + 4H^2O = C^9H^4I^2O^3 + 2CO^2 + 8HCl$$

On adding potash to the yellow liquid thus obtained (after separation of a tity of iodopyromeconic acid) impure iodomecone is obtained as a blac which redissolves on agitation. The addition of potash must be discontin as this precipitate exhibits a lighter colour, no longer redissolves on agit not increased by fresh additions; and by then collecting the precipitate, it with cold water, and repeatedly crystallising it from boiling alcohol, ic obtained in the pure state. It may be obtained in the same manner fro comenic acid, which differ from pyromeconic acid only by the elements anhydride.

Iodomecone forms shining yellow hexagonal plates, having an odour v that of saffron; it has neither an acid nor an alkaline reaction, sublimes is insoluble in water, soluble in alcohol and in ether, insoluble in hydr which does not decompose it even at the boiling heat. It is decompose nitric acid, and with aid of heat by strong sulphuric acid. Caustic potas boiling, abstracts from it a small portion of iodine.

IODOMECONIN. See Meconin.

IODOMELANILINE. See Melaniline.

IODOMERCURATES. Compounds of mercuric iodide with the iodides. (See Mercury, Iodides of.)

IODOMETHYLAMINE. See Methylamine.

IODOMETHYL-SELENIOUS ACID. See Selenious Ethers.

IODOMORPHINE. See Morphine.

IODONICOTINE. See Nicotine.

IODONITROHARMINE. Syn. with Di-iodide of Nitroharmine

IODONITROPHENIC ACID. See Phenic acid, Derivatives of.

IODOPAPAVERINE. See Papaverine.

IODOPHENYLAMINE. See Phenylamine, Derivatives of.

IODOPHENYLCITRACONIMIDE. See Citraconic acid, (i. 993).

IODOPIANYL. Syn. with Iodomeconin.

IODOPLATINATES. Compounds of platinic iodide with the iodides. (See Platinum, Iodides of.)

IODOPROPYLENE. See Allyl, Iodides of (i. 142).

IODOPYRITE. Syn. with Iodite.

IODOPYROMECONIC ACID. See Pyromeconic acid.

IODOQUININE. See Quinine.

IODOSALICYLIC ACID. See Salicylic acid.

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IODOSTRYCHNINE. See STRYCHNINE.

IODO-SUBSTITUTION COMPOUNDS. Iodine, though generally speaking very similar in its action to chlorine and bromine, acts for the most part less energetically, and is much less disposed to form substitution-compounds by direct action. Some compounds containing hydrogen, indeed, are acted upon by iodine in the same manner as by bromine or chlorine, part of the hydrogen being abstracted to form hydriodic acid, and its place being supplied by an equivalent quantity of iodine; such is the case with ammonia (iii. 280), ethylamine (ii. 536), methylamine, and phenylamine. But iodated organic acids cannot, for the most part, be formed in this way; to produce them from the original acids it is necessary to use chloride of iodine instead of free iodine, so that the superior affinity of the chlorine for hydrogen may remove it, and enable the iodine to take its place (p. 294) *e. g.*:

$$\underset{\text{Pyromeconic acid.}}{C^5H^4O^3} + ICl = HCl + \underset{\text{Iodopyromeconic acid.}}{C^5H^3IO^3}.$$

On the other hand, Kekulé (Chem. Soc. J. xvii. 206) has lately shown that many iodo-substitution compounds are decomposed by hydriodic acid, iodine being set free and the original acid reproduced, *e. g.*:

$$\underset{\text{Iodopropionic acid.}}{C^3H^3IO^2} + HI = \underset{\text{Propionic acid.}}{C^3H^4O^2} + I^2.$$

It is evident that where this reaction takes place, it is impossible that an iodised compound can be produced by the direct action of iodine on an organic acid. [For an exception, perhaps only apparent, to this rule, see SALICYLIC ACID.]

The action of hydriodic acid on iodated organic compounds just noticed explains the reducing action which it exerts on certain organic acids (p. 285). The reaction takes place in two stages, an iodo-substitution compound being first formed, and subsequently decomposed in the manner above explained. *e. g.*:

$$\underset{\text{Glycollic acid.}}{C^2H^4O^2} + HI = H^2O + \underset{\text{Iodacetic acid.}}{C^2H^3IO^2}.$$

$$\underset{\text{Iodacetic acid.}}{C^2H^3IO^2} + HI = I^2 + \underset{\text{Acetic acid.}}{C^2H^4O^2}.$$

IODOSULPHIDE OF ANTIMONY. See ANTIMONY (i. 338).

IODOTELLURATES. See TELLURIUM, IODIDE OF.

IODOTOLUYLIC ACID. See TOLUYLIC ACID.

IOLITE. Syn. with DICHROÏTE (ii. 320).

IONNAPHTHIN. This name is given by Carey Lea (Sill. Am. J. [2] xxxii. 211) to a colouring matter obtained in preparing naphthylamine from nitronaphthylene by the action of ferrous acetate (*Gmelin's Handbook*, xiv. 95, 5). If the mixture is heated before being treated with caustic potash, a faint red-coloured liquid distils over, which turns violet on addition of mineral acids, and if subsequently heated, assumes a dark purple-blue colour, and after a while yields a black crystalline precipitate, the quantity of which is increased by further heating; this is ionnaphthin. The crystals are black, with green metallic reflex, and dissolve in alcohol with blood-red colour, which, on addition of a very small quantity of sulphuric or nitric acid, changes to scarlet, and finally to purple-blue, is not altered by heating with sulphuric acid, but is changed to straw-yellow by hot nitric acid. From the brown mother-liquor, ammonia throws down dark-coloured flocks, which are insoluble in water and in alcohol, are blackened by dilute sulphuric acid and bichromate of potash, and then form a violet solution with dilute nitric acid.

IPECACUANHA. An emetic substance, the root of several plants growing in South America. All the kinds have nearly the same ingredients, but differ in the amount of the active principle (*emetin*) which they contain. The best is the annulated, yielded by *Cephalis Ipecacuanha*, a small shrubby plant of the rubiaceous order, native of Brazil and New Granada. It is found in commerce in pieces from 2 to 6 inches long and about the thickness of a straw, much bent or twisted, and sometimes branched, with a remarkably knotty character, owing to numerous circular depressions or clefts, which give the whole the appearance of a number of rings. It consists of a central axis called *meditullium*, and an external portion called the *cortical part*. Each of these contains emetin, but by far the greater portion exists in the cortical part.

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The following are analyses of different kinds of ipecacuanha:

	a	*b*		*c*
		Cortical part.	Medi-tullium.	
Fatty matter	1·2	2	trace	2
Wax		6		
Resin	1·2			
Emetin	16·0	16	1·15	14
Non-emetic extract	. .	. .	2·45	
Gum	2·4	10	5·00	16
Albumin	2·4			
Starch	53·0	42	20·00	18
Woody fibre	12·5	20	66·40	48
Gallic acid?	trace			
Loss	11·3	4	5·00	2
	100·0	100	100·00	100

a. Grey ipecacuanha, analysed by Barruch and Richard (the 2·4 per cent. gum includes saline matters). *b*. Blackish-grey, analysed by Pelletier. *c*. Reddish-grey, deprived of its meditullium, analysed by Pelletier. In an ash-grey variety, Pelletier found 9 per cent. fatty matter, 12 emetin, and 79 starch, gum, and woody fibre.

Another sort of ipecacuanha is obtained from the *Psychotria emetica*. This kind contains only 9 per cent. emetin; and the undulated or amylaceous ipecacuanha, the produce of *Richardsonia scabra*, contains only 6 per cent. emetin, with 92 per cent. starch. Besides these, the roots of numerous other plants are used in tropical countries as emetics, and often termed ipecacuanha. (Pelouze et Frémy, *Traité*, vi. 399.—*Penny Cyclopædia*, xiii. 17.—Rochleder, *Phytochemie*, s. 131.)

IPECUANIC ACID. An acid existing, according to Willigk (Ann. Ch. Pharm. lxxvi. 342), in the root of *Cephalis Ipecacuanha*. It is extracted from the root by boiling with alcohol, precipitating with basic acetate of lead, and decomposing the lead-salt with sulphydric acid. It is a reddish-brown, very bitter, amorphous mass, soluble in ether, more soluble in alcohol and water. It colours ferric salts green, the colour being changed to violet by ammonia. Its dilute solution does not precipitate neutral acetate of lead. When mixed with an alkali, it absorbs oxygen from the air and becomes coloured. It gives by analysis 56·22 per cent. C, and 6·23 H, whence Willigk deduces the formula $C^{14}H^{18}O^{7}$. Pelletier (Ann. Ch. Phys. iv. 172) regarded it as gallic acid.

IPOMEIC ACID. An acid produced by the action of nitric acid on rhodeoretic acid, a derivative of jalap-resin (*q. v.*) It agrees with sebacic acid in all its properties excepting its melting point—which is 104°, whereas sebacic acid melts at 127°—and in some of its relations to bases (Mayer, Ann. Ch. Pharm. lxxxiii. 143). See SEBACIC ACID.

IRIDIUM. Ir. *Atomic weight* 198·26.—The black scales which remain when native platinum is dissolved in nitromuriatic acid were found by Smithson Tennant (Phil. Trans. 1804) to consist of an alloy of two metals, iridium and osmium, hence called iridosmine. The same alloy occurs in flat white metallic grains in native platinum. Iridium has also been observed in combination with about 20 per cent. of platinum, crystallised in octahedrons, which are whiter than platinum, and are said to have a greater density, namely 22·66.

The separation of the osmium and iridium is effected by the following methods:—

1. The iridosmine is mixed with an equal weight of common salt, and subjected to the action of a stream of chlorine in a porcelain tube heated to redness. Double chlorides of iridium and sodium, and of osmium and sodium, are then formed, and if the chlorine is moist, a certain quantity of osmic acid, which volatilises, and may be condensed in aqueous ammonia. The mixture of the double chlorides is detached from the tube and boiled with nitric acid. Osmic acid is then evolved, and may be condensed in an alkaline solution, while the chloride of sodium and iridium remains in the solution, and, when mixed with sal-ammoniac, yields a precipitate of chloride of iridium and ammonium, which, on ignition, leaves metallic iridium. (Wöhler, Pogg. Ann. xxxi. 161.)

2. A mixture of 100 grms. of iridosmine and 300 grms. of nitre is placed in an earthen crucible, and heated to bright redness for an hour, the resulting mixture of osmate and iridiate of potassium poured out on a cold metal plate, then introduced into a tubulated retort, and distilled with a large excess of nitric acid. A large quantity of

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nses in the receiver in beautiful white crystals. acid ceases, water is added, and the residue, a certain quantity of oxide of osmium, is tromuriatic acid, which dissolves the two metals mixed with sal-ammoniac, which precipitates onium; and the mixed precipitate is suspended of sulphurous acid, whereby the chloriridiate of chloriridite, $(NH^4)^2Ir^2Cl^6$, which dissolves, while is unaltered, and does not dissolve: this latter by calcination. The solution of chloriridiate of beautiful brown crystals, which by calcination npt. rend. xviii. 144.)

ins platinum as well as other metals of the same ated by the methods just described. The com- f the platinum group has of late years formed the ons, which will be more fully considered under ing to iridium are the following:

latinum depends upon the ready convertibility of ssium to a lower degree of chlorination by the asy solubility of the resulting double chloride. harm. civ. 368) treat chloriridiate of ammonium of cyanide of potassium, adding the solution n digest it at a gentle heat till the undissolved own colour. The chloriridiate of ammonium is ssium, which easily dissolves, whereas the chloro- ing agent much longer, and remains undissolved. ly indicated by the change of colour of the un- small quantity of the iridium-salt gives a deep

d by sulphocyanate of potassium, the action of le, but somewhat more complex. It is better, ammonium by sulphydric acid, or by sulphurous), because metallic iridium may then be imme- the filtered solution of the chloriridite of am- (Claus, Ann. Ch. Pharm. cvii. 129; Jahresb.

after the complete exhaustion of platinum ore of two substances, one of which is scaly and ium, while the other, which is granular, contains nium, but is very rich in iridium and rhodium. right redness in a porcelain tube through which id by passing through potash, and from organic l) is drawn by means of an aspirator, osmic acid the latter crystallising in the colder part of the id is carried forwards (see Osmium and Ruthe- dium remains behind. To separate these metals, in an earthen crucible with four times its weight the process too far; and the product is exhausted filtrate consists of an alkaline solution of osmite g completely removed by the previous roasting, the iridium and rhodium, together with potash, is precipitate with nitromuriatic acid for several loriridiate of potassium, which may be dissolved l remaining undissolved. (Frémy, Compt. rend.

which state it may be brought by calcining it in eight of zinc, till the flame no longer exhibits h 3 pts. peroxide and 1 pt. of nitrate of barium, The black friable substance remaining in the te of barium containing ruthenium, is freed from itromuriatic acid; the baryta is then precipitated d required (this quantity being known from the ltrate mixed with excess of hydrochloric acid is nixed, towards the end of the operation, with a he residue, no longer smelling of acid, is washed, al-ammoniac (which dissolves out the rhodium, o the platinum group) till the liquid no longer

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runs away coloured, then with a more dilute solution of the same salt; the residue, chiefly consisting of chloriridiate of ammonium, is dried, heated to commencing redness (so as to decompose the ammonium-salts completely, the chlorides of the platinum metals imperfectly), then in a current of hydrogen to complete the reduction; and the resulting metallic sponge, in which the metals are not alloyed, but only mechanically mixed, is treated with nitromuriatic acid, which completely removes any platinum that may still be present, but leaves behind a certain quantity of osmium. The remaining pulverulent metallic mass is then fused with a mixture of nitrate and hydrate of potassium; and the unattacked portion of the metal, after being carefully freed from rutheniate of potassium by washing with water, is heated to whiteness in a crucible lined with charcoal, in which it bakes together; then placed in a vessel of lime and ignited in an oxy-hydrogen flame containing excess of oxygen, till every trace of the odour of osmium has disappeared; and lastly, fused at the strongest heat which the oxy-hydrogen flame is capable of producing. (Deville and Debray, Ann. Ch. Phys. [3] lvi. 385; Rép. Chim. pure, 1859, p. 541; Jahresber. 1859, p. 241.)

6. An intimate mixture of 100 pts. iridosmine or platinum-residues, 100 pts. nitrate of barium and 200 pts. caustic baryta, is heated in a red-hot earthen crucible; and the fritted mass, after being pulverised, is thrown by small portions into cold water, then mixed with nitric acid, and heated till all the osmium is driven off as osmic acid. A small quantity of hydrochloric acid is then added; the liquid is heated and filtered through gun-cotton; and the iridium is separated from the other metals contained in it, as in the preceding method. (Deville and Debray, Compt. rend. liv. 1138.)

7. Platinum-residue, finely pulverised and freed by levigation from the coarser grains of osmide of iridium, is gently ignited in a covered crucible, then mixed with 1 pt. finely granulated lead and 1½ pt. litharge, and heated, with stirring, in a thick-bottomed hessian crucible till the mixture becomes perfectly fluid. By this means all the silicates and earthy minerals present are converted into a slag; the metals more oxidable than lead are oxidised; and the specifically heavier platinum-metals collect in the lead-regulus. The latter, after being freed from slag, is dissolved at a gentle heat in nitric acid diluted with 1½ vol. water, which dissolves principally copper and palladium, leaving a residue which, when washed by decantation, consists of a fine black metallic powder of iridium, rhodium, and ruthenium, together with fine grains and scales of iridosmine, which must be separated by levigation. The black powder is immediately available for further treatment; the iridosmine, on the other hand (together with the coarser grains obtained by levigating the crude platinum-residue), is reduced to powder by fusing it in a charcoal crucible with twice its weight of granulated zinc, and then raising the heat to whiteness to drive off the zinc (p. 315). The finely divided iridosmine, is then heated in a stream of oxygen to expel the osmium, and the residue, together with the black powder of iridium, rhodium, and ruthenium above-mentioned, is mixed with an equal weight of chloride of sodium, and decomposed by Wöhler's method with chlorine gas (p. 314). The dark brown solution thus obtained is mixed with a little hydrochloric acid and one-fourth of its bulk of ordinary nitric acid, and distilled to one-third, the osmic acid which passes over being condensed by ammonia; the remaining liquid, which contains the double chlorides of iridium, &c., is mixed, while still warm, with an equal volume of a saturated solution of sal-ammoniac; and the red-brown precipitate, after standing for some days, is separated from the liquid, and washed with sal-ammoniac solution till the liquid runs off colourless. The wash-water contains the whole of the rhodium-salt, the mother-liquor consists chiefly of chloride of iron and ammonium, with traces of iridium, rhodium, and gold. The precipitate, consisting of chloriridiate of ammonium contaminated with platinum and ruthenium-salt, is mixed, after drying, with 1½ pt. cyanide of potassium, and melted for 10 or 15 minutes in a capacious porcelain crucible; the cooled mass is dissolved in the smallest possible quantity of water; and the yellow filtrate (after the whole of the free cyanide of potassium has been decomposed by dilute hydrochloric acid) is precipitated by sulphate of copper. The resulting precipitate, consisting chiefly of platino- and iridio-cyanide of copper, is washed with boiling water, first by decantation, then on a filter, and finally decomposed with boiling baryta-water, whereby oxide of copper is separated, and the platinum and iridium are converted into platino- and iridio-cyanides of barium, which are easy to separate, the platinum-salt, which is much more soluble in hot than in cold water, separating out completely at first, and the white iridium-salt crystallising afterwards. The mother-liquor of the iridium-salt contains a small quantity of ruthenio-cyanide of potassium; any rhodium-salt that may be present may be precipitated by acetic acid. (C. A. Martius, Ann. Ch. Pharm. cxvii. 357; Jahresber. 1860, p. 202.)

8. The following process is given by Deville and Debray (Ann. Ch. Phys. [3] lxi. 5; Jahresb. 1861, p. 889) for obtaining iridium, pure or alloyed, from the substance

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known in the Russian mint as "iridium-oxide"—a not quite uniform mixture containing iridium as oxide, and having the following average composition:

Volatile substances (and oxygen)	28·0
Soluble salts (NaCl and $CaSO^4$)	12·0
Platinum	3·8
Rhodium	1·8
Palladium	0·4
Copper	0·6
Iron	0·7
Iridium (and loss)	52·7
	100·0

The substance is ignited in a crucible lined with charcoal; and the residue is washed with water, heated with strong sulphuric acid to the boiling point of that liquid, and again washed with water, whereby all the soluble salts are removed, together with the copper and iron. If the amount of platinum is known, and the object is to prepare an alloy, the washed metal is heated to whiteness (to give it a compact texture), and then fused before the oxy-hydrogen blowpipe. To obtain pure iridium, the crude metallic powder, after treatment with sulphuric acid, is digested with nitromuriatic acid, the greater part of the iridium (with traces of rhodium) then remaining behind.

Metallic iridium is obtained from the chloride by reducing that salt with hydrogen at a red heat, or by exposing it alone to a very high temperature, or more easily by igniting the chloriridiate of ammonium (p. 314), in the form of a grey metallic powder much resembling spongy platinum. It is the most refractory of all bodies excepting ruthenium and osmium; not being fusible in the flame of the ordinary oxy-hydrogen blowpipe. Children, however, by the discharge of a very large voltaic battery, succeeded in melting it into a globule which was white and very brilliant, but still a little porous, and had a density of 18·68; and Deville and Debray, by means of their powerful oxy-hydrogen blast furnace, have fused it completely into a pure white mass, resembling polished steel, brittle in the cold, somewhat malleable at a red heat, and having a density equal to that of platinum, viz. 21·15. By moistening the pulverulent metal with a small quantity of water, pressing it tightly, first between filtering paper, then very forcibly in a press, and calcining it at a white heat in a forge-fire, it may be obtained in the form of a compact, very hard mass, capable of taking a good polish, but still very porous, and of a density not exceeding 16·0. After strong ignition it is insoluble in all acids, but when reduced by hydrogen at low temperatures, it oxidises slowly at a red heat, and dissolves in nitromuriatic acid. It is usually rendered soluble by fusing it with nitre and caustic potash, or by mixing it with common salt, or better with a mixture of the chlorides of potassium and sodium, and igniting it in a current of chlorine, thereby it is converted into the soluble chloriridiate of potassium or sodium.

IRIDIUM, ALLOYS OF. 1 pt. of iridium combines at a white heat with 4 pts. of copper, forming a ductile, pale red alloy, which is much harder than copper, and gives up its copper to nitric acid, the iridium remaining in the form of a black powder.

With gold, iridium forms a malleable alloy, having a colour very much like that of gold: nitromuriatic acid dissolves out the gold and leaves the iridium.

1 pt. of iridium and 8 pts. lead heated together to an intense red heat, form an alloy which is very ductile, but much harder and whiter than lead, and behaves with nitric acid like the copper alloy. On cupellation, the iridium is left as a soft black powder.

With mercury, iridium forms a viscid amalgam, which is obtained by immersing sodium-amalgam in an aqueous solution of chloriridiate of sodium. When very strongly ignited, it leaves a black powder, from which boiling nitric acid extracts a small quantity of mercury, leaving a residue of pure iridium, soluble in boiling nitromuriatic acid. (Böttger, J. pr. Chem. xii. 252.)

The compound of iridium and osmium is not, properly speaking, an alloy, inasmuch as osmium is rather a metalloïd than a metal. (See IRIDOSMINE.)

Platinum and iridium easily melt together, and form alloys which, even when they contain 20 per cent. of iridium, are still malleable and capable of being worked, but are less easily attacked by chemical reagents than pure platinum. (Deville and Debray.)

Equal weights of the two metals form a brittle alloy capable of welding to a certain extent. The alloy of platinum with a few parts per cent. of iridium is ductile and much harder than pure platinum, and more capable of resisting the action of fire and of chemical reagents (Berzelius). An alloy made by fusing 1 pt. iridium and 10 platinum in the

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flame of the oxyhydrogen blowpipe, is very malleable, susceptible of harden not tarnish, and when laid on copper serves for metallic mirrors. (Gaudi Chem. xvi. 55.)

A native alloy of iridium and platinum called native iridium occurs in in cubo-octahedrons of specific gravity varying from 21·85 to 22·65 and 22· Brazil in white round grains of specific gravity 16·94. (Svanberg, *Gmelin'* vi. 393.)

	Pt.	Ir.	Rh.	Pd.	Os.	Fe.	Cu.	
Ural .	19·64	76·85	. .	0·89	. .	. .	1·78	=
Brazil .	55·44	27·79	6·86	0·49	trace	4·14	3·30	=

1 pt. of iridium unites but imperfectly with 2 pts. of silver. (Vauqueli

1 pt. of iridium unites with 4 pts. of tin at an intense red heat, forming a d easily crystallisable, hard, malleable alloy. (Vauquelin.)

When iridosmine is fused with from 5 to 6 times its weight of tin, the all kept for a long time at a red heat in the charcoal crucible, then slowly co treated with hydrochloric acid, tin passes into solution, together with traces of and there remains a mixture (separable by a fine sieve) of finely pulverulent c osmium, and large shining cubic crystals of an alloy of tin and iridium, whi attacked by nitromuriatic acid, but when strongly ignited in an atmosphere of dric acid, gives off the whole of the tin, amounting to 56·6 per cent., as leaving 43·4 per cent. iridium.—By fusing tin with a mass containing iridium, and rhodium, and dissolving the excess of tin in hydrochloric crystalline residue is obtained, whose composition (if Pt denotes the platinu in general) is $PtSn^4$. (Deville and Debray.)

An alloy of iridium and zinc, obtained as in Deville and Debray's first m preparing an alloy of iridium and tin, is not crystallisable.

IRIDIUM, CARBIDE OF. When a coherent mass of iridium is he flame of a spirit-lamp, black masses appear on its surface, which are s containing 19·83 per cent. carbon, or IrC^4. The carbon burns off readily in

IRIDIUM, CHLORIDES OF. Iridium appears to form four compou chlorine; but only two of them have been obtained in definite form.

The *dichloride*, $IrCl^2$, is said by Berzelius to be formed when p iridium is heated to low redness in chlorine gas. It is described as a dark o powder, insoluble in water, slightly soluble in hydrochloric acid, and formi salts with the chlorides of the alkali-metals. According to Claus, however (Pharm. lix. 255), the so-called dichloride of iridium is merely a mixtur trichloride with metallic iridium. The dichloride appears, however, to certain double salts (p. 322).

The *trichloride*, Ir^2Cl^6, is prepared by dissolving the sesquioxide in hy acid, and evaporating; it also sublimes when iridium, either alone or mi nitre, is ignited in chlorine gas. It is black, deliquescent, and does not c It unites with the chlorides of the alkali-metals, forming double salts, called iridites, which are prepared, either by mixing the solutions of the c chlorides in the required proportions, and evaporating, or by reducing the of the corresponding chloriridiates with sulphurous acid, sulphydric acid or ferrocyanide of potassium. Claus has obtained the compounds $6NH^4$ $6H^2O$, $6KCl.Ir^2Cl^6.6H^2O$, and $6NaCl.Ir^2Cl^6.24H^2O$. They are olive-green, lent salts, soluble in water; the sodium-salt is also soluble in alcohol; two are insoluble in alcohol. Berzelius obtained a potassium-salt c $4KCl.Ir^2Cl^6$.

Chloriridite of silver, $Ag^6Ir^2Cl^{12} = 6AgCl.Ir^2Cl^6$, is produced, on adding silver to aqueous chloriridiate of potassium, as a deep indigo-coloured precipitate, which, however, becomes paler in a few seconds, and finally loses altogether. The reaction, which is attended with evolution of oxygen, is:

$$6AgNO^3 + 2K^3IrCl^6 + H^2O = Ag^6Ir^2Cl^{12} + 4KNO^3 + 2HNO^3 +$$

With a boiling solution of chloriridiate of potassium, the same compound immediately, without the intermediate production of a blue substance. T salt is insoluble in water and in acids, and but slightly soluble in ammoni it is covered with strong aqueous ammonia and left to itself for a few days, o dissolves, and the remainder is converted into a crystalline modification c composed of rhombohedrons having an adamantine lustre. (Claus, Ann. C lxiii. 338.)

The *tetrachloride*, $IrCl^4$, is obtained by dissolving very finely divide or one of its oxides, or the trichloride, in nitromuriatic acid, and he liquid to the boiling point. On evaporating the solution, it remains in of a black, deliquescent, amorphous mass, translucent with dark red col

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edges. It sustains a rather strong heat without decomposition, but at a higher temperature is reduced to the trichloride and ultimately to metallic iridium (Berzelius). It dissolves in water, forming a reddish-yellow solution. It unites with the alkaline chlorides, forming definite crystalline double salts called chloriridiates, the general formula of which is $M^2IrCl^6 = 2MCl.IrCl^4$. The *ammonium-salt*, $2NH^4Cl.IrCl^4.H^2O$ or $(NH^4)^2IrCl^6.H^2O$, is obtained, on mixing the solutions of the component chlorides, as a very dark brown precipitate, which dissolves in boiling water and crystallises in octahedrons on cooling. It dissolves in 20 pts. of cold water, forming a dark red brown liquid, and imparts distinct coloration to 4,000 pts. of water. The red colour often exhibited by chloroplatinate of ammonium is due to small quantities of this salt. The aqueous solution supersaturated with ammonia forms a pale yellow mixture, which becomes perfectly colourless when exposed to light, but afterwards turns purple, then violet, and finally assumes a beautiful blue colour.

The chloriridiates are easily converted, by the action of sulphurous acid, sulphydric acid, and other reducing agents, into the more soluble chloriridites, a reaction which affords the means of separating iridium from platinum, the chloroplatinates being but very slowly reduced under the same circumstances, and not converted into more soluble salts (p. 315).

The *potassium-salt*, $K^2IrCl^6 = 2KCl.IrCl^4$, is precipitated on mixing the aqueous solutions of its component salts. It may also be prepared by passing chlorine gas over a gently ignited and intimate mixture of finely divided iridium and chloride of potassium; filtering from unaltered iridium; dissolving the unfused black-brown mass in hot water; mixing it with nitromuriatic acid and evaporating to dryness; extracting the excess of chloride of potassium by small quantities of cold water; dissolving the residue in boiling water; adding a small quantity of nitromuriatic acid; and evaporating to the crystallising point. It crystallises in black octahedrons, yielding a red powder. It dissolves very slowly in cold water, but quickly in boiling water, forming a liquid which appears deep red in the mass, but yellow in thin films. It is insoluble in saline solutions and in alcohol, which precipitates it from solution in water. The aqueous solution, mixed with excess of potash, behaves in the same manner as the ammonium-salt with excess of ammonia. At a strong heat, it is converted into chloriridite of potassium, and at a still higher temperature, leaves metallic iridium mixed with chloride of potassium. The *sodium-salt*, $Na^2IrCl^6.6H^2O$ or $2NaCl.IrCl^4.6H^2O$, is obtained, like the potassium-salt, by passing chlorine over a gently ignited mixture of iridium and chloride of sodium. It forms black tables and four-sided prisms with dihedral summits, isomorphous with the corresponding platinum-salt. When heated, they leave the anhydrous salt in the form of a brownish-grey powder. It is easily soluble in water, and the solution mixed with sal-ammoniac yields a precipitate of chloriridiate of ammonium.

A *hexchloride* of iridium was obtained by Berzelius, in combination with chloride of potassium, by fusing iridosmine with nitre, distilling the product with nitromuriatic acid, and treating the residue with successive portions of water. A dark red solution was then obtained, which yielded a salt having the composition $6KCl.IrCl^4$, but according to Claus, the salt thus obtained was really a ruthenium-compound, having been prepared by Berzelius from iridosmine containing ruthenium. Pure iridium fused with nitre and distilled with nitromuriatic acid, yields a salt containing dichloride of iridium.

IRIDIUM, DETECTION AND ESTIMATION. Iridium in its free state is easily distinguished from all other metals, excepting rhodium and ruthenium, by its insolubility in acids, not being attacked in the compact state by any acid whatever, and in the state of fine division, only very slowly by nitromuriatic acid. Its infusibility, even in the ordinary oxy-hydrogen blowpipe flame, serves also to distinguish it from all metals excepting rhodium, ruthenium, and osmium.

It may be distinguished from rhodium by fusing it in the finely divided state with acid sulphate of potassium. The iridium is then converted into sesquioxide, but does not dissolve in the acid sulphate or colour it red, as rhodium does. Another method of distinguishing iridium from rhodium, and likewise from ruthenium, is to mix it intimately with chloride of potassium or sodium, heat the mixture in a stream of chlorine, and dissolve the resulting double chloride in water: iridium thus treated yields a black-brown solution, rhodium a rose-red, and ruthenium an orange-yellow solution. (See RHODIUM and RUTHENIUM.)

All compounds of iridium are easily reduced to the metallic state by ignition in an atmosphere of hydrogen; the reduced metal may then be tested in the manner just described.

Iridic solutions (containing the dioxide or tetrachloride), which are those of most frequent occurrence, are of a dark brown-red colour; iridous solutions (containing the sesquioxide or trichloride) have an olive-green colour. The characters of an iridic solution are best observed with chloriridiate of sodium, as all the other compounds are but very slightly soluble.

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Caustic *potash* in excess decolorises the solution of an iridic salt, changing red colour to a very faint greenish tint, and after some time throws down black-brown precipitate of chloriridiate of potassium. If the clear solution b and then left in contact with the air, it first acquires a faint red and the colour, gradually increasing in intensity from the surface downwards, and u becoming as deep as that of an ammoniacal solution of copper. The solutio rated to dryness, leaves a white mass, which, when treated with water, yields less solution and an insoluble blue powder consisting, according to Claus, hydrate. This is the most characteristic of all the reactions of iridium. The of *palladium* interferes, however, with the production of the blue colour, and to the precipitation of iridic oxide. A solution of iridium containing *platinu* wise not coloured blue by potash, but is decolorised, and yields a red preci chloroplatinate of potassium containing iridium; on heating the liquid, this p redissolves, and another precipitate is formed consisting of platiniferous iridi If the solution contains *rhodium*, no alteration takes place at first; but subs a light yellow precipitate of rhodic hydrate is produced; or if the solution is precipitate is of a dirty greyish-green colour, and the solution becomes colourl

Ammonia in excess also decolorises iridic solutions, and forms a slight blac cipitate. On boiling the solution for some time, till the greater part of the is expelled, the solution acquires a blue colour, especially if left exposed to but the colour is neither so pure nor so deep as that produced by potash. sence of palladium, platinum, or rhodium modifies the reaction with ammonia the same manner as with potash. *Carbonate of potassium* forms a red-brow pitate, which gradually dissolves, the liquid afterwards turning blue when ex the air. *Carbonate of ammonium* imparts a blue colour to the liquid unde fluence of the air. *Sulphydric acid* decolorises the solution at first, and af forms a brown precipitate. *Chloride of ammonium* forms a dark cherry-red, lent precipitate of chloriridiate of ammonium. *Ferrocyanide of potassium* a *sulphate of iron* decolorise the solution. *Dichloride of tin* forms a ligh precipitate. *Zinc* precipitates metallic iridium as a black powder.

Quantitative estimation and separation.—Iridium is completely tated from the solution of an iridic salt by treating the solution with chlorid monium or chloride of potassium, and then adding alcohol containing ether, in v chloriridiate of ammonium or potassium is quite insoluble. The precipitate collected on a weighed filter, washed with alcohol and ether, dried in the wa and then weighed. The ammonium-precipitate contains 44·21 per cent., the po precipitate 40·38 per cent. iridium. The ammonium-precipitate may also, after with ether-alcohol (not on a weighed filter), and drying, be carefully ignited i platinum crucible, and the weight of the remaining iridium directly determine

If the iridium exists in solution as sesquichloride, it must, before precipit converted into dichloride by passing chlorine gas into it, or heating it wit muriatic acid.

The mode of precipitation just described serves for the separation of iridi all metals excepting platinum, rhodium, ruthenium, and osmium; and from except rhodium, it may be separated by reducing it to the state of sesquichlo then adding to the liquid an excess of a concentrated solution of sal-ammoniac ridite of ammonium, $6NH^4Cl.Ir^2Cl^6$, is then formed, which is soluble in sal-a whereas the double compounds of chloride of ammonium with the chlorides of platinum-metals (except sesquichloride of rhodium) are insoluble in excess of of ammonium.

The reduction of dichloride of iridium in solution to sesquichloride may b by any of the reducing agents already mentioned (pp. 315, 319), but the most co for analytical purposes is *sulphydric acid*.

When, for example, iridium is to be separated from platinum, both bein form of tetrachlorides, the mixture of these compounds, or rather their dou with chloride of ammonium or potassium, may be treated with a small qu water, and solution of sulphydric acid added by small portions. The reducti iridic chloride then takes place immediately, a green liquid being formed, milky by precipitated sulphur, and coloured brown by sulphide of platinu metal is present in rather large proportion. Iridium is not precipitated from tions as sulphide by sulphydric acid at ordinary temperatures, unless the added in very large excess, and even then the precipitation takes at least The reduction of the iridium to trichloride being complete, sal-ammoniac is excess, and the liquid filtered. The platinum then remains undissolved, iridium passes into the filtrate, and may be reconverted into tetrachloride by nitromuriatic acid, and precipitated as already described.

The same method may serve to separate iridium from osmium, but the s

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ers of the group is generally effected by distillation
ing in an atmosphere of oxygen. (See OSMIUM.)
from iridium by precipitation with cyanide of mer-
iridium; also by fusion with acid sulphate of
adium, but merely oxidises the iridium.
hodium may be effected, when the former is in the
in the state of trichloride, by treating the solution
um, which forms, with trichloride of rhodium, a
ride of ammonium, whereas chloriridiate of ammo-
salt. Another mode of separation is founded on the
soluble, and chlororhodiate of sodium insoluble, in
h acid sulphate of potassium, whereby rhodium is
idised, serves for the qualitative distinction between
adapted for quantitative separation, because the
ce but slowly, and when a small quantity of it is
y of iridium, not a trace of it is taken up by the
M.)

—The only known determination of this number is
Pogg. Ann. xiii. 435), and founded on the analysis of
Cl^4. 100 parts of this salt ignited in a stream of
Now, as only 4 at. chlorine are given off, the
decomposed, we have, for determining the atomic
and Cl = 35·5), the proportion

$$+ Ir : 142 = 100 : 29$$
$$Ir = 198{\cdot}26.$$

(Oppler, *Ueber die Jodverbindungen des Iridiums*
ahresb. 1857, p. 263).—Iridium appears to form
ly, IrI^2, Ir^2I^6 and IrI^4.

iridious iodide, appears to be formed, as a brown
gas into water in which iridic iodide is suspended.
iriridiate of ammonium in a boiling concentrated
d leaving the liquid to stand for a few hours, *hypo-*
^{4} or $2NH^4I.IrI^2$, separates as a black crystalline
s.

ious iodide, separates as a black crystalline pre-
onium to aqueous iodiridiate of potassium, K^2IrI^6
bably formed in the first instance, and subsequently
, iodide of ammonium, and free iodine). It is
r, somewhat more freely in hot water, insoluble in
odides, forming double salts which may be called
$(NH^4)^6Ir^2I^{12}.2H^2O$ or $6NH^4I.Ir^2I^6.2H^2O$, separates
other-liquor of hypo-iodiridite of ammonium (see
first together with the latter, afterwards alone.
ates on adding a concentrated solution of iodide of
loride of iridium, as a fine crystalline powder.
in water and in alcohol, dissolving slowly in
ated. The *silver-salt*, $Ag^6Ir^2I^{12}$, is obtained on
tion of iod-iridiate of potassium, as a dark green
erwards turns brown. The reaction by which
f nitrate of silver on chloriridiate of potassium

idic iodide, is obtained as a soft black powder
a strong solution of tetrachloride of iridium, and
d with a little hydrochloric acid. With alkaline
. The *ammonium-salt*, $(NH^4)^2IrCl^6$, or $2NH^4I.IrCl^4$,
a solution of chloriridiate of ammonium in cold
otassium, in dark brown shining crystals easily
solution, when gently heated, becomes turbid and
idite of ammonium, $(NH^4)^2IrI^4$, and iridic iodide.
IrI^4, separates after the iridic iodide itself, from a
ith iodide of potassium. It is formed also, though
of iodine-vapour on an intimate mixture of iridium
60°—70°; and in larger quantity, by adding iridic
otassium, the latter being kept in excess; or by dis-

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solving the iridic iodide in iodide of potassium, and leaving the soluti
It forms dark, metallic-shining, crystalline spangles, appearing as oct
the microscope, easily soluble in water, insoluble in alcohol; it is di
and, with decomposition, by alkalis. The *sodium-salt*, $Na^2IrI^6 = 2NaI.$
on adding a concentrated solution of iodide of sodium to iridic ch
brownish-green crystalline powder, insoluble in alcohol and in cold
soluble in hot water.

IRIDIUM, OXIDES OF. Iridium forms four compounds with
IrO, Ir^2O^3, IrO^2, and IrO^3. The *protoxide*, or *Hypo-iridious ox*
little known. It is obtained by precipitating an alkaline hypochloriri
alkali in an atmosphere of carbonic anhydride (p. 323); but on expos
is quickly converted into a higher oxide. (Claus.)

The ***sesquioxide***, or ***Iridious oxide***, Ir^2O^3, was formerly regar
easily formed and most stable of the oxides of iridium; but, accord
has a great tendency to take up oxygen and pass to the state of diox
prepared by gently igniting a mixture of chloriridite of potassium (6
carbonate of sodium in an atmosphere of carbonic anhydride; on trea
with water, the sesquioxide remains in the form of a black powder i
(Claus, Ann. Ch. Pharm. lix. 251). It forms two hydrates, one cont
other 5 at. water. The **trihydrate**, $Ir^2O^3.3H^2O$, is obtained by treat
the olive-green sesquichloride, or one of its double salts, with potash
black precipitate, which, when treated with hydrochloric acid, yields
of olive-green sesquichloride. The **pentahydrate**, $Ir^2O^3.5H^2O$, is ob
the solution of either of the double salts of trichloride of iridiu
quantity of caustic potash, and leaving the liquid for some time to itse
and perfectly filled bottles. It is then deposited as a yellowish precipi
of olive green; but it cannot be obtained pure, as it easily takes up
blue, and being partially converted into dioxide. It dissolves in the s
of potash.

Sesquioxide of iridium unites with bases, forming salts which may be
A solution of a chloriridite in excess of lime-water deposits, after st
time out of contact of air, a dirty yellow precipitate containing Ca^3Ir^2O
(Claus, J. pr. Chem. lxxx. 282; Jahresb. 1860, p. 207.)

The ***dioxide***, or ***Iridic oxide***, IrO^2, is, according to Claus,
prepared and most stable of all the oxides of iridium, and is always
form of a bulky, indigo-coloured hydrate, $Ir^2O^2.2H^2O$, when a solut
the chlorides of iridium or their double salts is boiled with an alkali
retains 3 or 4 per cent. of the alkali. The hydrate may also be obtai
the hydrated sesquioxide in potash and treating the solution with an a
blue precipitate is then formed, which gradually absorbs oxygen fr
assumes an indigo-colour. The hydrate parts with its water when heat
in acids, forming solutions which are dark brown when concentrated
when dilute.

The ***trioxide***, or ***Periridic oxide***, IrO^3, is formed, according
iridium is fused for some time with nitre. The resulting blackish-
solves in water, forming a deep indigo-coloured solution of basic periridi
leaving a black crystalline powder consisting of acid periridiate. Th
washed, is perfectly neutral and tasteless, and dissolves with indigo-
chloric acid, giving off a very large quantity of chlorine. The qu
in it is variable, but the iridium and oxygen (in the acid) constan
proportion of 1 to 3. (Claus, Ann. Ch. Pharm. lix. 249.)

IRIDIUM, OXYGEN-SALTS OF. Iridium, like the other
shows but little tendency to form oxygen-salts. The oxides dissolve
definite salts are obtained in this way. The solution of iridic oxide
has a dark brown colour, which is not modified by potash in the same
of the tetrachloride, neither does it yield any blue precipitate on boilin

The only definite oxygen-salts of iridium that have been obtained
containing sulphurous and hyposulphuric acids.

α. *Hypo-iridoso-potassic Sulphite.* $3(K^2O.SO^2).IrO.2SO^2 = \frac{(S\dot{O})}{IrK}$
salt is obtained as a white powder when the mother-liquor obtained in
iridite of potassium by passing sulphurous anhydride through a soluti
iridiate (p. 318), is evaporated to a small bulk. It is somewhat cr
tasteless, insoluble in water, but dissolves easily in hydrochloric acid
phurous anhydride, and yielding a yellow prismatic salt, in which
replaced by 6 at. Cl. It dissolves in potash, forming a solution whi

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dic hydrate. The crystals contain 5 at. water, which perature, the salt is completely decomposed. (Claus,

with Chloride of Potassium, $6KCl.(IrO.2SO^2)$.—h hydrochloric acid. The resulting yellow solution w prisms, very soluble in water, and having an . At a red-heat it gives off sulphurous anhydride, iridium with chloride and sulphate of potassium.

$.(2K^2SO^3.IrSO^3.SO^2).12H^2O$ is obtained by heating ium with acid sulphite of potassium till the green evaporating. It forms minium-red crystals, yields with carbonate of potassium in an atmosphere of ed by prolonged heating with acid sulphite of potas-Claus, Ann. Ch. Pharm. cvii. 129.) In a former 4–348) Claus represented this salt by the formula which the protoxide of iridium was supposed to be uric anhydride S^2O^4Cl. The same acid may be ing salts:

by treating the preceding salt with hydrochloric ls, easily soluble, with yellow colour, in water, l crystals contain 5 and 6 per cent. water ($=4HO$), alis slowly decompose the salt, and nitromuriatic to an iridic salt. Its composition might also be $.(2KCl.Ir^2Cl^2)$; but it appears to contain a proto-iridium.

s salt is contained in the mother-liquor of δ, and coloured, viscid mass, which dries up to an amor-ing a yellow powder. It is decomposed by water, is converted into the white salt α. (Claus, Ann. *elin's Hand-book*, vi. 388.)

F. Four of these compounds are described, analo-y precipitating the solutions of the chlorides with *de*, IrS, obtained also by heating either of the is grey or blackish-blue. According to Berzelius, it po-iridious or iridious sulphate; and in sulphide phide of platinum. The *sesquisulphide*, Ir^2S^3, is a soluble in water [? when partially oxidised], and ith nitric acid and sulphide of potassium (Ber-obtained by precipitation, also by igniting chlor-ual weight of sulphur (Vauquelin); by igniting nd an alkaline carbonate, and exhausting the pro-ogg. Ann. lix. 66); and by mixing a solution of alcohol with sulphide of carbon, and leaving the ek. It is then converted into a gelatinous mass, d on a filter, washed with alcohol, then repeatedly ed. The product thus obtained is disulphide of vn powder, which is decomposed by heat, leaving ium according to the temperature to which it is by precipitation behaves with nitric acid and with otosulphide. The *trisulphide*, IrS^3, is obtained by ulphydric acid, but to complete the decomposition, ic acid must be left for a considerable time in a yellow-brown precipitate, which behaves like the id and sulphide of potassium. (Berzelius.)

ONIACAL. *Ammonio-dichloride of iridium, monium*, $N^2H^6Ir''.Cl^2$, is prepared by heating tetra-converted into dichloride, dissolving the brown ammonia, and adding hydrochloric acid in slight arates in the form of a yellow granular preci-oxide corresponding to this chloride has not The *sulphate*, $N^2H^6Ir''.SO^4$, is obtained by heat-nuric acid. It crystallises in large orange-yellow —*Tetrammonio-dichloride of iridium*, $4NH^3.IrCl^2$,

, $N^2H^4\overbrace{(NH^4)^2}Ir''.Cl^2$, is obtained as a white preci-

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pitate, by boiling the compound, $N^2H^6Ir''.Cl^2$, with excess of ammonia. Treated with moderately strong sulphuric acid, it yields the corresponding sulphate $(N^2H^4(NH^4)^2Ir''.SO^4$ in rhombic prisms; and, by decomposing this salt with nitrate of barium, or the chloride with nitric acid, the nitrate is obtained in yellow needles, which dissolve readily in water, melt when heated, and then suddenly decompose with flame.—*Chloronitrate of ammiridammonium*, $N^2H^4(NH^4)^2Ir''\left\{\begin{matrix}(NO^3)^2\\Cl^2\end{matrix}\right.$, or *Nitrate of ammochloriridammonium*, $N^2H^4(NH^4)^2(IrCl^2).2NO^3$, analogous to Gros' platinum-nitrate, is obtained as a yellowish, crystalline, granular mass, by heating the chloride of iridammonium, $N^2H^6IrCl^2$, with strong nitric acid; when recrystallised from water, it forms shining, yellow, laminar crystals.—*Dichloride of ammiridammonium*, $N^2H^4(NH^4)^2Ir''.Cl^2$, or *Chloride of ammochloriridammonium*, $N^2H^4(NH^4)^2(IrCl^2).Cl^2$, is obtained by treating the last-mentioned salt with hydrochloric acid, in the form of a violet precipitate, which dissolves readily in hot water, and separates from the solution in violet crystals. Nitrate of silver added to the solution throws down only half the chlorine. The nitrate, treated with dilute sulphuric acid, yields the chlorosulphate of ammiridammonium, in delicate greenish, needle-shaped crystals. (Skoblikoff, Ann. Ch. Pharm. lxxxiv. 275.)

The compound $10NH^3.Ir^2Cl^6$, or $\left.\begin{matrix}N^2H^4(NH^4)^2Ir''\\N^2H^2(NH^4)^4Ir''\end{matrix}\right\}Cl^6$, is obtained by mixing a dilute solution of chloriridite of ammonium, $(NH^4)^6Ir^4Cl^{12}$, with excess of ammonia, and leaving the mixture in a well-closed and completely filled bottle for some weeks in a warm place; heating the liquid, which has then acquired a rose colour, to expel the excess of ammonia; neutralising with hydrochloric acid, evaporating to dryness, and treating the greenish-yellow residue with cold water to extract the chloride of ammonium. A light flesh-coloured, finely crystalline powder then remains, which, when dissolved in boiling water acidulated with hydrochloric acid, yields on cooling, a crystalline precipitate of $10NH^3.Ir^2Cl^6$, mixed with trichloride of iridium. This compound, when dissolved in a boiling solution of ammonia, is partially decomposed, with separation of blue hydrated dioxide of iridium; when digested with water and oxide of silver, it yields a rose-coloured alkaline solution of the base $10NH^3.Ir^2O^3$. This solution, saturated with various acids, yields crystalline salts, soluble in water, namely, a *carbonate*, $10NH^3.Ir^2O^3.3H^2CO^3$, as a light flesh-coloured, finely crystalline, alkaline powder; a *nitrate*, $10NH^3.Ir^2O^3.3N^2O^6$, in indistinct, light flesh-coloured, neutral prisms; and a sulphate, $10NH^3.Ir^2O^3.3SO^3$, also neutral and of similar colour. (Claus, *Beiträge zur Geschichte der Platin-metalle*, Dorpat, 1854; Jahresb. 1854, p. 434.)

IRIDOSMINE. *Native iridium, Osmide of Iridium, Osmium-iridium, Iridosmium, Newjanskite, Sisserskite.*—This compound occurs, together with platinum, in the province of Choco in South America, in California, Oregon, Australia, and in the Ural mountains; also in the gold washings on the rivers du Loup and des Plates, Canada. It sometimes constitutes the principal part of platinum ore, especially of that from Katharinenberg, Slatoust, and Kischtin in the Ural. It occurs rarely in hexagonal prisms with replaced basal edges, commonly in irregular grains, flat or round, sometimes in very thin laminæ. It has a metallic lustre, tin-white or light steel-grey colour, and is slightly malleable. Hardness = 6 to 7. Specific gravity = 19·3 to 21·12.

The following are analyses of specimens from different localities:—1. By Thomson (*Gmelin's Handbook*, vi. 425).—2. By Claus (*Beiträge &c.*).—3. By Berzelius (Pogg. Ann. xxxii. 232).—4–8. Deville and Debray (Ann. Ch. Phys. [3] lvi. 385; Jahresb. 1859, p. 767).

	Os.	Ir.	Rh.	Pt.	Ru.	Cu.	Fe.	
1. Brazil	21·5b	72·90	. .	. .	. .	. .	2·60	= 100
2. Nischna Tagilsk, *hexagonal plates*	27·32	51·24	1·51	10·08	5·85	. .	. .	= 100
3. Katharinenberg, *laminæ*	49·34	46·77	3·45	. .	. .	. .	0·74	= 100
4. Oregon, *thin shining scales*	17·20	70·40	12·30	0·10	6·00	. .	. .	= 100
5. ,, *round compact grains*	35·10	57·80	0·63	. .	6·37	0·06	0·10	= 100
6. California, *Cavernous nodules*, sometimes filled with oxide of iron or chromic iron ore	43·40	53·50	2·60	. .	0·50	. .	. .	= 100
7. Australia, *extremely thin laminæ*	33·46	58·13	3·04	. .	5·22	0·15	. .	= 100
8. Borneo	38·94	58·27	2·64	0·15	. .	. .	. .	= 100

Iridosmine has usually been regarded as consisting of definite osmides of iridium (the iridium being more or less replaced by rhodium, ruthenium, and platinum); No. 1 agreeing nearly with the formula Ir^3Os; 2, with IrOs; and 3, with $IrOs^3$. But according to Deville and Debray, it is not a homogeneous substance, and cannot be regarded as a distinct mineral species.

Iridosmine, when heated in the air, gives off osmic acid, with greater facility as it is

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richer in osmium, and becomes dull. When ignited for some time with nitre alone, or with nitre and caustic potash, it gives off part of the osmium as osmic acid, and forms osmate of potassium, together with iridiate of potassium (p. 314). According to Fischer (Pogg. Ann. xviii. 258) it is more easily decomposed by nitrate of calcium, and according to Deville and Debray (p. 316) by a mixture of peroxide and nitrate of barium. Nitromuriatic acid has scarcely any action upon it. [For the methods of analysing it, see IRIDIUM, pp. 315, 316, 320; also PLATINUM-RESIDUES.]

IRISINE. See CHINOLINE (i. 871).

IRITE. This name was given by Hermann, J. pr. Chem. xxiii. 276) to a black mineral from the Ural, crystallised in regular octahedrons and consisting of the protoxides of iridium, osmium, and iron, combined with the sesquioxides of iron and chromium. According to Claus (*ibid.* lxxx. 285) it is a very variable mixture, consisting chiefly of iridosmine and chrome-iron ore.

IRON. Synonyms: *Eisen; Fer; Ferrum; Mars.* Symbol: Fe. Atomic weight: 56. Equivalents: Fe = 28 (ferrosum); fe = 18⅔ (ferricum).

This metal, although the most abundant of the heavy metals, and most largely employed in the arts, is but little known in a state of absolute chemical purity. The iron met with in commerce always contains carbon, and generally some other foreign substances, altogether varying in amount from 0·5 to nearly 10 per cent. Probably all these admixtures exercise some influence on the characters of the metal; but it appears to be chiefly the amount of carbon contained in iron, which determines the remarkable differences of character presented by the several varieties of metallic iron known as malleable iron, cast iron, and steel.

Pure iron is described as resembling silver in whiteness, capable of receiving a very high polish, extremely tenacious, softer than ordinary malleable iron, and presenting a scaly, conchoïdal, or sometimes crystalline fracture. Specific gravity, after melting 7·8439, in sheet or wire 7·75 to 7·60.

Iron obtained by electrolysis was found to have a specific gravity of 8·1393. Its malleability was not affected by heating to redness and rapid cooling, nor was it in the least degree hardened by this treatment. It was scarcely acted upon by acids at the ordinary temperature; but dissolved with the aid of heat, evolving hydrogen quite free from the peculiar smell observable in the hydrogen evolved during the solution of ordinary iron. (Percy, *Metallurgy*, ii. 2.)

The crystalline form of iron is either the cube, octahedron, or some other form belonging to the regular system.

The different kinds of iron employed in the arts may be comprised under three heads, viz. malleable iron, cast iron, and steel, the latter being to some extent intermediate in its characters between the other two, and combining some of the peculiarities of both. See STEEL.

The difference between these three kinds of iron is, however, by no means absolute, even as regards their characters, but more a difference in the degree in which particular characters are presented. Iron approaching nearest to a state of purity requires a very high temperature for its fusion, while cast iron melts at a comparatively low heat, but, not being sufficiently malleable, it cannot be wrought into any required shape. Malleable iron has a much higher degree of toughness or tenacity than cast iron, which on the other hand is much harder, while steel may be melted and forged, as well as rendered hard or soft at will, or as it is technically termed "tempered," by cooling suddenly or gradually; on account of these varied combinations of qualities, the different kinds of iron have a wide range of applicability to a great diversity of purposes.

Leaving out of consideration for the present all the other substances met with in iron except carbon, it appears that the greater or less approximation to the character of pure iron is so uniformly accompanied by very slight differences in the amount of carbon, that these two circumstances may be regarded as having a very intimate causal connection.

Karsten's observations lead to the conclusion that iron containing 0·65 per cent. carbon, and free from any other substance, becomes so much hardened by plunging it into water, while red-hot, that it may be regarded as steel. When the amount of carbon is as much as 1·4 or 1·5 per cent. the metal presents the maximum combination of tenacity with the capability of hardening by sudden cooling. Increase in the amount of carbon beyond this limit is accompanied by increased hardness, but the tenacity and malleability are less. With 1·75 per cent. carbon, the malleability of the metal is very slight, and with 1·9 per cent. it scarcely admits of being wrought. Iron with 2·3 per cent. carbon presents, when melted and gradually cooled, indications of graphite being separated during the cooling, and the other characters of cast iron, which may contain an amount of carbon varying from this minimum limit up to 5·75 per cent.

These limits, however, are somewhat different when iron contains other substances,

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as is usually the case: thus, taking as the criterion between malleable iron and steel, the capability of acquiring, by sudden cooling, such a degree of hardness as to give sparks when struck with flint, this is generally found to obtain with iron containing 0·5 per cent. when it also contains small quantities of silicon, sulphur, phosphorus, &c.

Taking as the criterion which distinguishes cast iron from steel, the separation of graphite when the melted metal is slowly cooled, and the want of malleability in the cold, it is found, in like manner, that the relation between these characters and the amount of carbon is not strictly constant, but that it is to some extent modified by the nature and amount of other admixtures, not only by their rendering the metal less malleable, but also by their promoting the tendency to the separation of carbon.

Malleable Iron (*Schmiedeisen; Stabeisen; Fer doux*).—Ordinary malleable iron has a grey colour, which varies in its shade according to the character of the iron, and has sometimes a bluish or blackish tinge.

The specific gr ty varies between 7·3 and 7·9; that of the better kinds generally approximating to the mean of these two values. The specific gravity is affected to some extent by the alteration of internal texture produced mechanically. Thus a bar 4 inches wide and 1 inch thick with a specific gravity = 7·8010 acquired a specific gravity = 7·8621 when rolled out to very thin sheet, and iron of specific gravity 7·7938 acquired a specific gravity = 7·8425 when drawn into very thin wire. (Karsten.)

The specific heat of ordinary malleable iron is 0·113795, and is somewhat higher when the amount of carbon in the metal is large. (Regnault.)

The conducting power for heat is 374·3 compared with gold = 1000. (Despretz.)

The linear and cubical expansion by heat (see HEAT, iii. 68, 71) is less than that of most other metals. The linear expansion for each degree between 100° and 300° C. = $\frac{1}{88\,190}$. (Dulong and Petit.)

An iron bar expands $\frac{3}{560}$ when raised from a red heat to a white heat, and $\frac{7}{560}$ when heated from 20° C. to whiteness. (Rinman.)

The melting point of malleable iron has not been determined with any degree of certainty. It is between the melting point of cast iron and that of platinum, and is estimated at 1550° C. by Pouillet, and at 2000° C. by Scheerer, and there is no doubt that it is higher in proportion as the metal contains less carbon.

Pure iron is attracted by the magnet more powerfully than iron containing carbon, and it may be rendered magnetic; but it does not retain the magnetic condition so long as iron containing some carbon. Ordinary bar iron is also attracted more strongly than steel, and is more easily rendered magnetic, but loses the polar condition much sooner than steel does. It appears therefore that the presence of a certain amount of carbon is in some way necessary for the retention of the magnetic condition by iron. Bars of iron placed vertically or nearly so become, in course of time, magnetic. The magnetic condition of iron is very nearly destroyed by a red heat, and entirely so by exposure to a white heat.

The electric conductivity of iron is much less than that of copper. Taking this as = 100, that of iron is = 20 (Harris), 15·8 (Becquerel), 17·74 (Lenz). Matthiessen considers that the electric conductivity of electro-deposited iron is much higher than that of ordinary malleable iron.

	Conductivity at 0° C.	Percentage decrement in conductivity between 0° and 100° C.	Deduced conductivity of pure iron at 0° C.
Electrotype iron	100	38·3	
Plate iron . .	91·8	36·0	102·7
	72·8	34·1	102·1
	84·6	34·7	99·2

The hardness of malleable iron varies considerably; it is influenced by the presence of foreign substances, and reduced by increase of temperature. It is however but very slightly increased by sudden cooling of the red-hot metal; the less so the smaller the amount of carbon contained in it. A certain amount of carbon seems essential to the hardness of malleable iron. Absolutely pure iron is so soft that it offers but little resistance to friction.

The tenacity of iron also varies widely, and is influenced by the nature and amount of foreign admixture in the metal, as well as by its internal texture, by temperature, and by other conditions. Up to a temperature of 146° C., the tenacity of boiler plate is not sensibly diminished; but at a red heat it is reduced one fourth. The tenacity of good rivet iron at 190° C. is a third greater than at the ordinary temperature; but at a red heat it is reduced to nearly one half. (Fairbairn, *Useful Information for Engineers.*)

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Tenacity or tensile strength of iron.

Kind of iron.	Lengthwise in pounds per square inch.	Crosswise in pounds per square inch.	Ultimate extension.	Authority.
Lowmoor iron wire	64,200	52,490	. .	Fairbairn.
Staffordshire bar iron	from 62,231 to 56,715	. .	0·302 to 0·186	Kirkaldy and Napier.
Swedish bar iron	from 48,232 to 47,855	. .	0·264 to 0·278	"

(See Kirkaldy, Trans. Instit. of Engineers in Scotland, 1858–9; and *Tensile Strength of Wrought Iron and Steel*, London, 1862.—Fairbairn, Brit. Assoc. Report, 1856.)

The malleability of iron is very considerable, though less than that of silver or gold. It is influenced by the presence of foreign substances which modify the hardness and tenacity, the degree of malleability being apparently determined by the relative hardness and tenacity, and to some extent also by its internal texture. The malleability of iron is increased in proportion as its temperature is raised, inasmuch as it then becomes softer without its tenacity being proportionally lessened. At a red heat it is sufficiently soft to be brought to any required shape by hammering or rolling, and at a white heat it becomes quite pasty, so that separate pieces may be, as it were, kneaded together into one mass; or, as it is termed, *welded*. This capability of being forged and welded, so important as regards the methods by which iron is wrought for various uses, is referable to the wide interval between the temperature at which the metal presents its ordinary degree of hardness, and that at which it becomes liquid; as well as to the fact that, at temperatures far below the melting point, it acquires a soft plastic condition, which is retained in a greater or less degree through a considerable range of temperature.

Among the foreign substances influencing prejudicially the malleability of iron, the chief are sulphur, phosphorus, and silicon. The first communicates to it the character of being brittle while hot, or, as it is called, "red short" in forging. Phosphorus renders iron "cold short," or brittle and weak at the ordinary temperature. Silicon has a similar influence in a higher degree. Manganese seems to be beneficial rather than otherwise as regards the malleability of iron. The malleability of iron is considerably reduced by immersing it while red-hot in cold water, as well as by long continued hammering and by rolling, but it is again restored by heating the metal to redness, and allowing it to cool gradually.

The texture, or molecular structure of iron varies very considerably according to the treatment to which it has been subjected. After being melted, iron is decidedly crystalline or granular, and its fracture presents distinct indications of that condition. By hammering or rolling while hot, it acquires a fibrous or silky texture, becomes more tenacious, less susceptible of true fracture, and capable only of being torn asunder. In the usual method of producing malleable iron, it is not melted, but wrought mechanically while in a kind of doughy condition, and the uniform close fibrous texture which determines the quality of the metal depends much upon the nature of this treatment and the extent to which it is carried.

By hammering while cold, fibrous iron is rendered harder and brittle; when afterwards broken, it presents a granular or crystalline fracture, but opinions differ as to whether this crystalline condition be really a result of the hammering. This is also the case with regard to the influence of long continued pressure, vibration, or concussive action, in affecting the texture of iron, some maintaining that these conditions slowly destroy the fibrous texture, rendering the iron crystalline and thereby weaker. (Rankine, Proceedings of Inst. of Civil Engineers, 1843; Percy, *Metallurgy*, ii. 8.)

Malleable iron undergoes no change in dry air, or in water free from air; but in moist air, or in water containing air, it gradually becomes oxidised or rusted, from the surface inwards, until eventually the entire mass may be converted into oxide. The carbonic acid present in atmospheric air appears to contribute largely to the production of this change. The presence of saline substances in water also facilitates the oxidation of iron; while alkalis, and oily or resinous substances, retard the oxidation. (Mallet, *Action of air and water, &c., upon cast iron, wrought iron, and steel*, Brit. Assoc. Reports, 1838, p. 253; 1840, p. 221.) Contact with more highly electro-positive metals, such as zinc, also hinders the oxidation of iron within a certain distance around the point of contact.

At a temperature about 230° C., iron becomes capable of combining directly with atmospheric oxygen, and the polished surface at first becomes covered with an extremely thin film of magnetic oxide, of a yellow colour which gradually passes into red, blue, and grey. At a red heat this crust of oxide—*forge scale*—becomes thicker, and gradually passes at its outer surface into ferric oxide. At a white heat, iron burns

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in the air, with production of magnetic oxide, and this combustion may be sustained for some time by directing a blast of air upon the metal.

At a temperature about 360° C. iron decomposes water-vapour, forming magnetic oxide and liberating hydrogen.

Pure iron dissolves completely in moderately dilute acids. Ordinary malleable iron dissolves completely in strong hydrochloric acid: but with dilute acid a carbonaceous residue remains undissolved. In both cases also the hydrogen evolved carries with it carbonaceous vapour, which communicates to it a peculiar smell.

Malleable iron generally contains from 0·25 to 0·5 per cent. carbon; sometimes the amount is much less. The smaller the amount of carbon, the softer is the iron, and

Analyses of best qualities of Foreign Malleable Iron.

Source	Swedish. Österby.	Swedish. Gysinge. (B)	Swedish. Löfsta. (L)	Silesian; Rybnik.	Russian iron. CCND	Russian iron. K.ЗКБ	Swedish. Kloster.	Mägdesprung.		Dannemora.
Analyst	Henry.			Karsten.	Henry.			Bromeis.		Schafhäutl.
Iron	99·863	99·220	99·544	99·73	99·873	99·412	99·594	98 605	98·88	99·13	98·78
Carbon	0·054	0·087	0·087	0·24	0·090	0·272	0·340	0·386	0·40	0·66	**0·84**
Silicon	0·028	0·056	0·115	0·03	0·030	0·062	trace	0·252	0·01	trace	0·12
***Sulphur**	*0·055	*0·632	*0·220	. .	0·007	*0·234	*0·066	*0·757	trace		. .
Phosphorus	trace	0·005	0·034	trace	. .	. .	. .	trace	. .		. .
Manganese	trace	. .	. .	trace	. .	0·020	trace	trace	0·30	0·29	0·05
Copper	. .	. .	. .	. .	. .	. .	. .	. .	0·32	0·05	0·07
Arsenic	. .	trace	trace	. .	. .	trace	. .	. .	. .	. .	0·02
	100·000	100·000	100·000	100·000	100·000	100·000	100·000	100·000	99·91	100·13	99·88

Analyses of British Malleable Iron.

	South Wales.			Shropshire.
		Puddled bar.		Best bar.
Works		Dowlais.		
Analyst	Schafhäutl.	Riley.		Price.	
Iron	98·90	7·72	98·54		
Carbon	**0·41**	.	not estimated		
Silicon	0·08	0·26	0·13	0·18	0·18
Sulphur	. .	**0·21**	**0·05**	**0·06**	**0·03**
Phosphorus	**0·40**	**0·71**	**0·42**	**0·37**	**0·30**
Manganese	0·04				
Manganese, nickel and cobalt	. .	0·03	0·22	. .	trace
	99·83	100·00	100·00		

Armour and Boiler Plate.

Works	Lowmoor.	Thames Iron Co.	Beale & Co.	Shortridge & Howell.		Weardale.	Russell's Hall.
Analyst	Tookey.	Percy.	Percy.	Percy.	Percy. La Gloire.	Percy.	Henry.
Iron	99·372	. .	. .	. .	. .	. .	99·361
Carbon	**0·016**	**0·033**	**0·044**	**0·230**	**0·143**	**0·170**	**0·190**
Silicon	0·122	0·160	0·174	0·014	. .	0·110	0·144
***Sulphur**	***0·104**	***0·121**	***0·118**	***0·190**	***0·058**	***0·058**	***0·165**
Phosphorus	**0·106**	**0·173**	**0·228**	**0·020**	**0·030**	**0·089**	**0·140**
Manganese	0·280	0·029	0·250	0·110	. .	0·330	. .
Nickel	trace						
Cobalt	trace	trace	trace	trace	. .	trace	. .
	100·000						100·000
Specific gravity	7·8083	7·7035	7·6322	7·9042	. .	. .	. .
Tensile strength	24·644	23·354	24·171	27·032	. .	. .	. .
Relative resistance to punching	1000	907	873	1168	. .	. .	. .

*The results to which this mark * is put are probably much too high. See *Estimation of Sulphur*, p. 372.

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s it approximate to the character of steel. The only
carbon is that known technically as "burnt iron,"
Hence it has been supposed that the capability of
presence of carbon in iron. There are, however, no
more probable that the peculiarity of "burnt iron"
e of carbon, and is determined by the presence, in
xide, which could not have been introduced so long

other than carbon, present in malleable iron, the
orus, and silicon, existing probably in combination
netal, as sulphide, phosphide, and silicide.
some extent in malleable iron, and, even when
has the effect of rendering it "red short," and
g. It has been considered that 0·01 per cent. is
the usefulness of the iron. (Karsten, *Handbuch*

ent, and, when amounting to 0·75 per cent., renders
the ordinary temperature, or, as it is called, "cold
onsidered to be serviceable in rendering the iron
arsten, *op. cit.*)
d lessens its tenacity, making it what is termed
esent to the extent of only 0·37 per cent.
r iron harder, but not to make it steely.
on "red short," and to reduce the capability of
cting the tenacity of the metal.
hat the evidence upon which the above opinions, as
s upon the character of malleable iron, are founded,
sirable that this subject should be more thoroughly

nethods of manufacturing it, will be treated of in a

n; Gusseisen; Fonte).—There are two essentially
and white.
Fonte grise) varies in colour from pale to dark grey.
of malleability; but is harder and more brittle than
lar; sometimes very fine-grained, sometimes coarse-
e particles of graphite visible throughout the mass.
en, Fonte blanche) varies in colour from that of tin
brittle; of crystalline lamellar texture, and some-
shining, and varies from lamellar to compact and
colour varies from tin-white to grey. The most
lar iron (*Spiegeleisen; fontes lamelleuses*).
iron is, on the average, 7·1; that of white cast iron

1600° C., and more easily in proportion as the
ter. White cast iron melts at a lower temperature;
nen melted as the grey cast iron, which passes sud-
state, while the white cast iron remains in a pasty
iron dissolves malleable iron, and is thus rendered
ly (toughened cast iron). White iron, when cooled
e, is converted into grey cast iron. Grey cast iron,
ly cooled from a melted state, is not altered except
eable; but when rapidly cooled, it is converted into
etely in proportion as the amount of carbon it con-
count the outer surface of a casting has a hard crust
quence of the more rapid cooling of that portion of
ntact with the sides of the mould, and its conversion
often augmented, in practice, by lining the mould
he rapid cooling of the outer portions of the casting,
iron, from $\frac{1}{8}$ to $\frac{1}{2}$ an inch thick, while the interior
iron, thus combining the particular advantages of
, and of grey cast iron as regards strength.
rge masses of cast iron there is an inequality in the
e metal at the exterior and interior portions. In
cooled from a melted state, the centre portion con-
r portions. There is also a further difference as to
n exists. At the centre, the relative proportion of
combined carbon, is greater than it is at the exterior

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portions. This latter difference will be more marked in proportion as the melted metal is more rapidly solidified at the surface. In one instance of iron cast in an iron mould, referred to by Karsten, the following results were obtained:—

	Total quantity of carbon.	Combined carbon.	Graphite.
Cast iron before melting . . .	4·0281 . .	= 0·7812 . .	3·2469
Outer white portion of casting . .	5·0929 . .	= 5·0929	
Inner grey portion of casting . .	3·8047 . .	= 0·6106 . .	3·1941

The main chemical difference between white and grey cast iron consists in the state in which the carbon they contain exists. In specular iron, the whole of the carbon is combined with iron, while in the most characteristic kind of grey cast iron, when solid at least, the greater part of the carbon is merely mixed with the iron, in the state of graphite, and only a portion of it is in a state of combination. Between these two extremes there are a variety of intermediate states in which white and grey cast iron are mixed together in various proportions, constituting what is known as *mottled cast iron* (*halbirtes Gusseisen*; *fonte truitée*).

The hardness and strength of these varieties of cast iron differ considerably; as a rule, the grey is stronger than the white, and this again is harder than the grey. White cast iron is, however, too brittle to be used for structures, except for the purpose of coating the surface of castings with a hard crust or skin, by casting in moulds lined with metal (chill casting). (Rankine, *Civil Engineering*, p. 499.)

The tenacity of cast iron is very much less than that of malleable iron; but its capability of resisting crushing force is very much greater.

Kind of iron.	Direct Tenacity.	Resistance to direct crushing.	Modulus of rupture of square bars.	Modulus of Elasticity.
	In pounds per square inch.			
Cold blast . .	from 12,694 to 18,855	56,455 102,408	36,693 39,609	14,000,000 17,036,000
Hot blast . .	from 13,434 to 23,468	72,193 104,881	29,889 43,497	11,539,000 22,733,000
Toughened cast iron	from 23,461 to 25,764	129,876 119,457		

The strength of cast iron is increased by remelting, but reduced when the melting is repeated several times. At very low temperatures it becomes more brittle and weaker. (Fairbairn and Hodgkinson, *Report on the Application of Iron to Railway Structures*, p. 265.)

The specific heat of specular iron = 0·12983, that of ordinary white cast iron = 0·12728. (Regnault.)

The linear expansion of cast iron by heat is greater than that of malleable iron, amounting to $\frac{7}{5000}$ between 20° and 560° C. (red heat), and $\frac{12}{560}$ between 20° and a white heat. (Rinman.)

Pieces of cold cast iron thrown into the melted metal sink to the bottom; but when they have a temperature near the melting point, they float on the surface of the melted metal. Hence it would appear that some degree of contraction takes place in the passage from the solid to the liquid state. This character of cast iron is important as regards its application to casting: for the increment of bulk attending solidification ensures the perfect filling of the moulds at that moment, and the production of sharp, well-defined castings. But the greatest amount of expansion or contraction takes place just below the melting point. On account of this contraction between a temperature near the melting point and the ordinary atmospheric temperature, it is necessary to make the moulds for castings proportionately larger than the castings are required to be. The contraction of grey cast iron amounts to about 1 per cent.; that of white cast iron is from 2 to 2·5 per cent. of the linear dimensions. The allowance generally made for this "shrinkage" in casting is $\frac{1}{96}$ or one eighth of an inch in a foot. Cast iron also undergoes a permanent increase of bulk under the long-continued influence of heat. (Percy, *Metallurgy*, ii. 872.)

White cast iron exposed to oxidising influences at the ordinary temperature, rusts much more slowly than grey cast iron, and this again, provided it does not contain much sulphur or other readily oxidisable substances, more slowly than malleable iron. Specular iron is but very little liable to oxidation.

At an elevated temperature, grey cast iron becomes coloured by oxidation sooner than malleable iron; white cast iron on the contrary becomes coloured even sooner

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than steel. When cast iron is heated to redness in the air, the carbon it contains is first oxidised and the metal rendered more or less malleable; then a crust of magnetic oxide is formed at the surface and gradually increases in thickness as in the case of malleable iron. Grey cast iron is most slowly oxidised in this way, and becomes porous and friable after abstraction of its carbon. White cast iron is decarbonised more rapidly, and acquires a malleable steely character. Upon this fact is based the manufacture of malleable cast iron, which consists in heating to redness the castings, while imbedded in powdered chalk, charcoal, or oxide of iron, so as to be partially protected from the oxidising influence of the air.

Cast iron melted in contact with air becomes covered with a crust of oxide, and by removing this crust from time to time, it may be entirely converted into oxide. If the crust is allowed to remain in contact with the melted metal, this gradually becomes decarbonised, steely and less fusible. White cast iron heated in contact with air till it assumes the pasty condition, is decarbonised much more rapidly than by mere heating to redness, and passes from the steely condition to that of pure iron, without so great a degree of oxidation as takes place when the metal is melted. The most important method of manufacturing malleable iron is based upon this fact (puddling).

Cast iron melted under soda, potash, lime, or magnesia carbonates, is gradually decarbonised, and may be wholly converted into malleable iron, if the heat be raised as the iron becomes less fusible.

Atmospheric air forced into melted cast iron oxidises the carbon and silicon, as well as part of the iron, and converts the remainder into malleable iron. The temperature produced in this way is sufficiently high to determine the fusion of the wholly decarbonised iron. (See STEEL.)

White cast iron heated with concentrated hydrochloric acid is entirely dissolved; but grey cast iron, treated in the same way, leaves a residuum of graphite. In both cases the combined carbon enters into combination with a portion of the nascent hydrogen eliminated by the solution of the iron, forming volatile oily hydrocarbons, the vapour of which communicates a peculiar smell to the gas evolved. This oily substance, which appears to be of a nature analogous to petroleum, also collects as a thin film on the surface of the acid solution.

The action of dilute hydrochloric acid upon cast iron is somewhat different. Specular iron is acted upon very slowly at the ordinary temperature, but with the aid of heat, both it and grey cast iron are readily dissolved. The hydrogen evolved has the characteristic smell, but the amount of the hydrocarbons formed appears to be smaller than when concentrated acid is employed. White cast iron leaves a bulky dark-brown carbonaceous residue, which is soluble in potash, and, when washed and dried is very readily combustible, leaving a black residue containing silica (Daniell, Journal of Science and the Arts, ii. 278). Grey cast iron leaves a residue consisting partly of graphite, partly of a carbonaceous substance similar to that obtainable from white cast iron, and, partly of a black carbonaceous substance which is magnetic, takes fire by contact with the air, and leaves when burnt a residue of ferric oxide.

Cast iron is slowly acted upon by sea-water. Cannon balls that had been lying in the sea off the coast of Normandy since 1692, were found to have lost two-thirds of their original weight, contained no metallic iron, and were converted into a substance that could be cut with a knife (Deslongchamps, J. Chim. méd. xiii. 89). Cannon balls taken from vessels sunk fifty years before, near Carlscrona, were found to be partly converted into a grey porous graphite substance, which after exposure to the air for a quarter of an hour, became so heated that the adherent water was converted into steam (Berzelius, *Gmelin's Handbook*, v. 218). The substance remaining after the action of sea-water, appears to be similar to that remaining, mixed with graphite and the bulky carbonaceous residue, after dissolving grey cast iron by dilute hydrochloric acid, and which Karsten regards as a compound of iron with three equivalents of carbon. Berzelius considered this solution of cast iron by sea-water to be due to the conjoint action of carbonic acid and oxygen. The solution of cast iron takes place at places where it is exposed to the combined influence of fresh water and sea-water by tides more rapidly than in sea-water. (Mallet, *op. cit.*)

The solution of cast iron takes place at places where it is exposed to the combined influence of fresh water and sea water, by tides more rapidly than in sea water.

The maximum amount of carbon in cast iron is met with in specular iron, varying from 5·75 to 5·24 per cent. Bromeis and Percy consider that the manganese present, so far as is yet known, in all specular iron containing as much as 5 per cent. carbon, is in some way essential to this high proportion of combined carbon.

In grey cast iron the amount of carbon varies, as a general rule, between 2 and 4·65 per cent.; in white cast iron it is from 3·5 to 5·75 per cent; but the difference between white and grey cast iron is more intimately connected with the state in which the carbon exists, than with the amount of this substance.

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Analyses of cast iron.

Ore used	Spathic iron ore			Magnetic iron ore		Frank-linite	Specular and brown iron ore	
Fuel used	Charcoal							
Source	Styria	Müsen	Bohe-mia	Dannemora		New Jersey	Nova Scotia	India Iron Co.
Analyst	Widter-mann	Fre-senius	Richter	Henry		Henry	Tookey	W. A.
Kind of iron	Specular iron						No. 1 grey	grey pig
Iron	94·68	82·860	. .	92·906	95·57	81·363	94·85	
Carbon combined	3·88	4·323	2·311	4·809	4·20	6·900		
Carbon graphitic	. .	. .	. .	. .	. .	. .	3·50	3·38
Silicon	0·41	0·997	2·732	0·176	0·08	0·100	0·84	0·44
Sulphur	0·02	0·014		trace	trace	*0·137	0·02	0·04
Phosphorus	0·04	0·059		0·122	0·05	. .	0·19	0·27
Manganese	0·98	10·707	22·183	1·987	0·10	11·500	0·44	0·14
Copper	. .	0·066						
Aluminium	. .	0·077						
Calcium	0·07	0·091						
Magnesium	0·01	0·045						
	100·04	99·954	100·00	100·00	100·00	100·00	99·84	
	1	2	3	4	5	6	7	8

Ore used	Clay iron ore of coal measures					Northampton clay iron ore and roasted tap cinder
Iron in ore	39·8		—	—	—	
Sulphur in ore	trace		—	—	—	
Phosphorus in ore	0·50		—	—	—	
Fuel used	Thick-coal coke		—	—	—	
Sulphur in fuel	0·50		—	0·31	—	—
	Staffordshire					
Name of works	Lays; Dudley		Level; Dudley	Nether-ton	Golden-dale	Russell's Hall
Analyst	Woolwich Arsenal					Henry
Kind of iron	hot blast		grey pig cold blast	hot blast	forge pig cold blast	No. 4 forge hot blast
Iron	. .	. .	. .	. .	. .	92·82
Carbon combined	. .	. .	. .	. .	. .	0·19
Carbon graphitic	2·87	3·34	3·21	2·56	2·61	2·81	2·54	2·45
Silicon	1·16	1·18	1·54	1·75	1·40	0·57	2·71	2·07
Sulphur	0·08	0·07	0·07	0·05	0·04	0·06	0·04	*0·32
Phosphorus	. .	0·55	0·23	0·63	0·72	0·29	1·07	1·43
Manganese	. .	. .	. .	0·06	0·49	0·13	0·98	0·72
Aluminium	. .	. .	. .	. .	. .	. .	. .	trace
Arsenic	. .	. .	. .	. .	. .	. .	. .	trace
	9	10	11	12	13	14	15	16

Ore used	Clay iron ore of coal measures							
Phosphorus in ore	—		—		0·41	0·73	—	
Fuel used	Barnsley coal		Deep hard coal and coke		Brand's hard coal		—	
Sulphur in fuel	0·65		—		0·52		—	
Name of works	East End; Wellingbro'; *Northamptonshire*		West Hallam *Derbyshire*		Butterley		Bowling; *Yorkshire*	
Analyst	Woolwich Arsenal.							
Kind of iron	cold blast No. 1 grey	cold blast mottled pig	hot blast forge pig	hot blast foundry	hot blast No. 2 pig	hot blast No. 4 pig	No. 1	No. 3
Iron								
Carbon, graphitic	2·85	2·10	2·57	2·40	2·74	2·60	2·90	2·80
Silicon	1·92	2·11	1·53	1·50	2·36	1·34	1·94	1·51
Sulphur	0·10	0·13	0·05	0·06	0·02	0·11	0·04	0·06
Phosphorus	1·19	1·07	0·70	0·34	1·21	0·75	0·57	0·44
Manganese	0·24	0·08	0·94	0·60	1·06	0·40		
	17	18	19	20	21	22	23	24

* Probably estimated too high. See *Estimation of Sulphur*, p. 372.

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cast iron—continued.

atite	Hæmatite	Cleveland ore	
		No. 4	No. 5
—	69·1		
—	—		
coal	trace		
	coke	coke	coke
—	1·09	1·05	0·91
LAND	Hæmatite Co., WHITEHAVEN; *Cumberland*	SOUTH BANK	STOCKTON ON TEES
		Durham	

Woolwich Arsenal

	hot blast ?			hot blast	
	No. 1 pig	No. 2 pig	No. 4 pig	No. 2 pig	No. 3 pig
.	. .	little	0·35		
83	3·22	2·24	1·86	3·04	3·31
59	3·02	2·77	2·63	2·73	1·43
03	. .	0·01	0·10	0·04	0·03
10	0·06	0·05	0·03	1·30	1·36
.	0·11	0·07	0·07	0·38	0·06
7	28	29	30	31	32

c iron ore	Clay iron ore
6—49·78	—
races	—
races	—

rham			*Scotland*		
	TOW LAW		CALDER	CLYDE	
	Riley	Tookey	Berthier		
o. 3 pig	No. 1 pig	specular iron	foundry pig		white pig
.	90·584	. .	94·63	92·30	92·24
.	. .	4·100	1·20	0·40	0·30
·15	2·795	. .	1·40	1·80	1·52
·18	4·414	0·230	1·53	2·80	1·79
.	trace				
·12	0·039	0·030	0·35	1·40	0·60
·19	0·099	0·073	0·39	1·30	0·95
ace	1·837	2·370	0·50	. .	2·60
.	traces	0·014			
35	36	37	38	39	40

ore of coal measures		Brown iron ore
—	56·53	—
—	—	—
—	0·32	—
ee-quarter coal coke	coke	coke
0·74	0·76	0·90
SOUTH WALES	PONTYPOOL	PARK END; *Dean Forest*

Woolwich Arsenal

	cold blast			cold blast	cold blast	
pig	No. 1 pig	forge pig		grey pig	No. 1 pig	grey forge
.	. .	} 2·37				
4	3·40			2·53	3·26	3·08
8	1·36	1·09		1·23	2·34	2·18
08	0·07	0·73		0·08	0·04	0·06
7	0·29	0·76		0·46	0·14	0·14
6	0·28	0·22		0·42	0·23	0·14
3	44	45		46	47	48

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Besides iron and carbon, cast iron always contains other substances, as ind the above analyses, especially silicon, sulphur, phosphorus, manganese, arsen They probably exist, in combination with equivalent quantities of iron, a sulphide, phosphide, &c., and some of them appear to exercise considerable upon the quality and characters of the metal, although the mode in which cised is but very partially understood, and the very nature of that influence cases dubious.

Silicon is almost always present in cast iron to some extent, originating deoxidation of silica in the process of smelting. The amount varies very r white cast iron it is generally from 0·1 to 0·5 per cent. In grey cast iron the much greater, and is seldom less than 0·5 per cent., sometimes exceeding even Karsten found 3·46 per cent. to be the maximum amount. The greater silicon in grey cast iron is considered to be due to the higher temperature a is produced. Iron produced with hot blast contains more silicon than that with cold blast.

It is generally considered that, within the ordinary limits as to the amount in cast iron, this substance does not exercise any prejudicial influence upon t of the metal; but, in the conversion of cast iron into malleable iron, the sil be as much as possible separated, since it is very detrimental to malleabl regards its tenacity. The greater the amount of silicon in pig iron, the great the waste incurred in its conversion into malleable iron by the puddling oper

Sulphur is almost always present in cast iron, but sometimes the amount i that it can hardly be estimated. It probably never reaches 0·5 per cent. in iron. Iron smelted with mineral fuel always contains more sulphur than tha with charcoal, in consequence of the sulphur contained in the coal or coke be ferred to the iron. The presence of sulphur in cast iron renders it more fu also more liable to solidify sooner when slightly cooled below the melting p to become quite viscid while still red-hot.

When specular iron is melted with sulphur, carbon separates and collects upo face of the melted mass in the form of graphite, which differs from ordinary in having no lustre. Grey cast iron melted with sulphur is converted into iron, containing a greater amount of carbon than the original grey iron, as the following results obtained by Karsten (*Eisenhüttenkunde*, i. 583):

	The grey cast iron contained in 100 pts.	The resulting wh contained in 10
Combined carbon . . .	0·6253	5·4878
Graphite	3·3119	
Sulphur.	0·0286	0·4464

Hence it would appear that sulphur displaces carbon existing in co with iron, but that up to a certain point, the carbon so displaced from co with one portion of the iron, enters into combination with another portion more can be taken up. The presence of sulphur in cast iron appears th determine the existence of the carbon in the state of combination with the thus to be conducive to the production of white cast iron. (Janoyer, Mines, 1851, iv. 20; Weston, *Percy's Metallurgy*, ii. 135.)

Phosphorus is frequently present in cast iron, sometimes to the extent of cent. When amounting to more than 0·5 per cent., it renders the iron brittle fusible, very liquid when melted, and capable of remaining longer in the liq Within certain limits, therefore, the presence of phosphorus in iron intended f is advantageous rather than otherwise.

Nitrogen.—It appears that cast iron sometimes contains a minute amount of and that it has a considerable influence on the character of the metal. S estimated the nitrogen in several kinds of cast iron as follows (Precht Encyklop. 1847, xv. 364; Phil. Mag. 1840, xvi. 44):

White cast iron (Maesteg, South Wales) . . .	0·764 per ce
Grey cast iron (Creusot, France)	0·720 „
Specular iron	1·200 „

Marchand's experiments led him to doubt the existence of nitrogen in and to infer that if it were present, it never amounted to 0·02 per cent., and indications of nitrogen obtained by analysis were generally referable to abso atmospheric nitrogen by the iron, and formation of cyanogen during the ana

Bouis (Compt. rend., 1861, lii. 1195) on the contrary, considers that nitroge present in cast iron, and has estimated the amount in a sample of very hard

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0·15 per cent. This subject, however, is far
ated.
opinion as to the influence of arsenic upon cast
presence, but there are some well-established
siderable amount of arsenic. Wöhler found it
häutl has stated that pig iron made at Alais
to 4 per cent. of arsenic. Karsten never de-
to Berthier's analyses of some iron shells and
9·8 to 27 per cent. arsenic, constituting in fact
ght shot from Sinope has been found to contain
Percy, *Metallurgy*, ii. 76.)
rsenic in cast iron, is considered to have the
metal more fusible, brittle, and weaker.
present in some kinds of cast iron, and it has
the metal. Several patents have been obtained
nded for the manufacture of steel (Mushet,
ber 1861), but it is very questionable whether
tion of known fact. The following analyses of

e same, with some fast aluminous ore.		Cornish ⅓, hæmatite ⅓, and Irish bog-ore ⅓, containing 6 to 9 per cent. manganese.		Cornish ⅔, Irish bog-ore ⅓.
. 2 pig.	grey pig.			
92·79	92·04	87·90	86·88	84·26
. .	. .	0·31	1·02	0·07
3·18	3·11	3·12	3·01	2·61
3·28	3·55	2·59	2·55	3·32
0·71	0·47	0·79	1·15	1·63
0·06	**0·11**	**0·03**	**0·03**	**0·02**
0·06	**0·09**	**0·15**	**0·15**	**0·20**
0·48	1·09	5·85	6·37	8·09
. .	. .	0·06	0·11	
. .	. .	0·06	0·04	0·06
00·56	100·46	100·85	100·31	100·27

the pig iron made from the ores of Taberg in
2, xi. 97), and in pig iron made from the Seend
n. Soc. [2] ii. 21.)
on, but there is no evidence to show whether it
ne metal.
t in cast iron, and it appears to have some in-
carburation of the iron, as well as the existence
on with the iron, so that its presence in the
ne production of white cast iron (See *ante*,
ganese appears to be especially suited for the
e Steel.)
n cast iron. When exceeding 0·2 per cent. it is
er, and stronger.
n smelted from ores containing zinc; and Karsten
f zinc to be very soft, but rotten and brittle.

d *Potassium* are sometimes indicated by analyses
me kinds of cast iron, but scarcely anything is
ters of the metal.
of the most abundant and widely distributed of
et with naturally in the metallic state. There
viz. telluric and meteoric iron.
occurs massive in plates and grains, is more
on; its specific gravity is from 7· to 7·8. It has
hæmatite and quartz in a lode near Grenoble
792); at Canaan, Connecticut, as a vein two

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inches broad in mica slate (Shepard). This specimen contained 91·8 per cent. iron iron and 7 per cent. carbon. It is said to be mixed with the granular platinum of South America (John), and disseminated through some basaltic rocks (Andrews), also in the auriferous sand of Oláphian (Molnar). Native iron containing 6 per cent. of silicon and a little sulphur is said to have been found with galena, in the lodes at Leadhills, and in volcanic scoriæ at Graveniére in Auvergne.

2. *Meteoric iron* is met with, both as large compact masses, and as grains and splinters disseminated through earthy meteorites. Its colour is somewhat like that of platinum, and it is characterised by always containing nickel, sometimes also cobalt, copper, chromium and tin. The masses of meteoric iron found in South America and Siberia, and estimated to weigh several tons, are among the most remarkable that are known. Meteoric iron almost always contains particles of iron sulphide mixed with it, apparently neither magnetic nor ordinary pyrites. (Rammelsberg, Pogg. Ann. 1849, lxxiv. 442.)

Analyses of Meteoric Iron.

Fell at	Bohumilitz, Bohemia, in 1829.	Krasnojarsk, Siberia.	Hraschina, Croatia, 1751.	Cape, Africa.	Clairborne, Alabama.	Potosi.	N. America.	Bitburg, near Treves.
Weight	103 lbs.	1600 lbs.	71 lbs.	300 lbs.	—	—	—	3300 lbs.
Analyst	Berzelius.		Wehrle.		Jackson.	Morren.	Silliman & Hunt.	Stromeyer.
Iron	93·78	88·04	89·78	85·61	66·56	83·57	92·58	81·8
Nickel	3·81	10·73	8·89	12·27	24·71	12·67	5·71	11·9
Cobalt	0·21	0·46	0·67	0·89	. .	. .	. .	1·0
Copper	. .	0·07	. .	. .	. .	. .	trace	
Manganese	. .	0·13	. .	. .	3·24	. .	. .	0·2
Chromium	. .	. .	. .	. .	trace			
Tin	. .	trace						
Magnesium	. .	0·05						
Arsenic	. .	. .	. .	. .	. .	. .	trace	
Sulphur	. .	trace	. .	. .	4·00	. .	. .	5·1
Iron sulphide	. .	. .	. .	. .	. .	2·30		
Carbon	. .	0·04						
Chlorine	. .	. .	. .	. .	1·48	0·91		
Insoluble	2·20	0·48	. .	. .	. .	. .	1·40	
	100·00	100·00	99·34	98·77	99·99	99·45	99·69	100·0

Iron ores. Compounds of iron occur native in great numbers as minerals, and very widely distributed; there are indeed few natural bodies in which iron is not present to some extent; it exists in the ashes of most plants (see i. 417, ii. 680), and appears to be an essential constituent of the blood of animals (see *ante*, p. 2). Of the native compounds containing iron in large proportion, those which occur in greatest abundance are the oxides, disulphide, carbonate, phosphate, titanate, and silicate. But for the extraction of the metal the only minerals that are suitable are the several oxides and the carbonate, all of which occur as large masses, of a greater or less degree of purity, being generally mixed with varying amounts of siliceous or earthy substances, and smaller quantities of various other minerals. The most important varieties of these ores of iron are the following:—

Native magnetic oxide, Magnetic iron-ore; Magneteisen; Oxyde magnetique.—This is the richest of the ores of iron available for smelting; in its purest state it contains 72·41 per cent. iron. It is black and generally has a metallic lustre, and occurs both crystalline, granular and compact or even earthy, at well as in the state of sand. It exists abundantly in many localities as beds or veins, and sometimes forming entire mountain masses, associated with volcanic or schistose rocks, and chiefly in Norway, Sweden, Siberia, and North America. It is sometimes largely mixed with pyrites and other sulphuretted minerals. In this country magnetic iron-ore occurs in the West of England and at Rosedale in Yorkshire.

The mineral known as *Franklinite* appears to be a variety of magnetic iron ore in which ferrous oxide is replaced by zinc oxide.

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of Magnetic Iron Ore.

	Cornwall.		Rosedale.		Danne-mora.	Frank-linite.
	Noad.		North-cutt.	Pattin-son.	Karsten.	Rammels-berg.
	44·40	66·50	12·22	32·67	70·23	64·51
	20·00	13·00	35·25	33·85	29·65	
	0·16	·56	. .	0·69	. .	13·51
	. .	. .	. .	. .	. .	25·30
	5·20	3·60	14·10	3·15		
	0·60	0·56	2·38	2·86		
	1·00	1·52	3·95	1·59		
	. .	. .	. .	trace		
	. .	. .	9·65	6·95		
	. .	. .	16·25	10·36		
	0 50	**0·57**	. .	**1·41**		
	0·04	**0·04**	**trace**	**trace**		
	. .	. .	**trace**	**0·03**		
	2·50	3·20	4·80	3·76		
	24·20	9·40	. .	0·84		
	99·60	98·95	98·60	98·16	99·88	103·32
	. .	. .	35·94	49·17	71·68	45·16

Red iron ore; Rotheisenstein; Fer oligiste.—In its
y of anhydrous ferric oxide containing 70 per cent.
rystalline, massive, and earthy, very often as lumps
d smooth surface, known as "kidney ore." It also

ses of Red Iron Ore.

	Ulverstone.		Cleator.	Ulver-stone.	Whit-church, South Wales.	
	Spiller.	R. Smith	Dick.		Ratcliffe	
	94·23	90·94	90·55	86·50	66·55	
	. .	. .	. .	. .	1·13	
	0·23	0·25	0·10	0·21	1·13	
	0·63	trace	1·43	0·30	2·79	
	0·05	0·99	0·71	2·77	9·40	
	trace	trace	0·06	1·46	1·39	
	. .	. .	. .	. .	0·42	
	. .	. .	. .	. .	0·15	
	4·90	6·68	7·05	6·18	8·90	
	. .	0·78	. .	2·96	5·73	
ace	**trace**	**trace**	**trace**	**trace**	**1·02**	
ace	**0·09**	**0·24**	**trace**	**0·11**	**1·31**	
ace	**0·03**					
	0·39	. .	. .	. .	2·12	
	0·17	. .	. .	. .		
	. .	. .	. .	. .	0·38	
	100·72	99·88	99·96	100·49	102·42	
60	**65·98**	**63·66**	**63·25**	**60·55**	**47·47**	

ted with quartz, calcspar, and heavy spar. Some
ble, and it generally contains varying amounts of
British deposits of hæmatite are in Cumberland and

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Lancashire, the Isle of Man, Devonshire and Cornwall. On the Continent it occurs chiefly in the Hartz, Silesia, the Austrian provinces, and in Norway. A peculiar oolitic hæmatite occurs in the neighbourhood of Liége.

Red ochre is an earthy variety of ferric oxide containing a large admixture of clay.

Specular iron ore; Eisenglanz; *Fer speculaire.*—This also consists of anhydrous ferric oxide in a crystallised form. Its colour is iron grey or almost black. Specific gravity 4·8 to 5·3. The crystals of this mineral belong to the hexagonal system, R.oR and sometimes $R.\frac{4}{3}P^2.\frac{4}{3}R$. It occurs chiefly in schistose rocks, in Norway, the Erzgebirge, in Russia, and several parts of the South of Europe, the most extensive deposit being that in Elba, which has been worked upwards of 3,000 years.

Specular iron ore often contains titanium, either in the form of rutile, or combined with the ferric oxide constituting ilmenite. This was formerly considered prejudicial to the ore; but quite recently it has been stated that the presence of titanium in iron ores, contributes in some way, not yet understood, to the production of good iron.

Native hydrated ferric oxide; Brown iron ore; Braunciseners; hematite brun.—This ore consists essentially of hydrated ferric oxide, which in the pure state contains 59·89 per cent. of iron and 14·44 per cent. combined water. It is sometimes indistinctly crystalline or fibrous; but more generally compact or earthy, and of various shades of colour from blackish-brown to yellowish-brown. This ore frequently contains a considerable amount of manganese, and a more or less considerable admixture of foreign earthy substances. It occurs abundantly in the Forest of Dean in Gloucestershire, in several parts of Devonshire and Northamptonshire, and Lincolnshire, as well as in Weardale, Durham, where it has originated chiefly by the alteration of spathic iron ore. On the Continent it is very abundant, and is one of the principal ores smelted in France and Germany.

A variety of this mineral occurs in many places under the name of bog iron ore (*Sumpferz; minerai des marais*), which has apparently been formed by deposition from ferruginous water under the influence of living organisms. Some kinds of this ore furnish very good iron—for instance, the lake ores of Sweden and Lower Canada; but generally it contains so large an amount of phosphorus as to be useless for smelting.

Yellow ochre is an argillaceous variety of hydrated ferric oxide containing more combined water than brown iron ore, and basic sulphate; sometimes also basic silicate, phosphate, and arsenate.

Analyses of Brown Iron Ore.

Source	Dean Forest.			Devonshire.	Northamptonshire.		Weardale.	
Analyst	Dick.		Price.	Dick.	Dick.		Tookey.	Spiller.
Ferric oxide	90·05	89·80	89·28	89·39	76·00	74·32	72·08	49·57
Ferrous oxide	. .	. .	. .	. .	trace	. .	. .	10·77
Manganous oxide	0·88	0·04	. .	0·33	0·40	0·57	6·60	3·06
Alumina	0·14	0·98	. .	0·52	2·30	2·91	0·40	0·84
Lime	0·06	0·51	. .	0·33	0·41	0·76	0·56	5·69
Magnesia	0·20	0·40	. .	0·20	0·11	0·18	1·90	1·21
Potash	. .	. .	. .	. .	. .		. .	0·05
Silica	0·92	2·14	0·98	1·42	5·33	6·03	4·09	6·64
Titanic acid								
Carbonic acid	. .	. .	. .	. .	. .	0·57	0·13	14·49
Phosphoric acid	0·09	0·13	trace	0·13	1·03	3·17	0·22	0·01
Sulphuric acid	traces	trace	. .	trace	. .	trace	. .	trace
Iron pyrites		. .	. .	trace	. .	0·06	. .	0·03
Water hygroscopic	. .	. .	9·74	8·83	1·80	. .	12·40	1·81
Water combined	9·22	7·05			12·40	11·89		6·63
Organic substance	. .	. .	. .	. .	. .	trace	. .	trace
	100·76	101·05	100·00	101·15	99·78	100·46	99·38	100·80
Percentage of iron	63·04	62·86	62·57	62·60	53·20	52·05	49·78	43·02

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Iron Ore—continued.

Lincoln-shire Brigg.	North-ampton-shire.	Dorset-shire.	Wilt-shire; Seend.	North-ampton-shire.	Corn-wall; St. Austle.
Tookey.	Percy.	Tookey.	Riley.	Spiller.	Riley.
58·10	56·20	55·21	53·48	52·86	51·87
. .	trace	. .	. .	trace	
0·88	0·20	0·95	1·60	0·51	0·43
4·95	2·43	7·70	4·38	7·39	4·01
4·15	0·49	0·70	0·84	7·46	0·52
0·96	0·17	1·15	0·72	0·68	0·17
11·70	29·07	19·65	26·23	13·16	36·03
1·08	. .	. .	trace	4·92	
1·40	0·84	0·42	0·87	1·26	0·49
. .	. .	0·16			
. .	. .	. .	trace	0·03	0· 3
16·46	1·16 9·74	13·11	13·61	. . 11·37	0·80 5·80
99·68	100·30	99·05	101·73	99·54	100·15
40·67	39·34	38·65	37·44	37·00	36·31

Iron Ore—continued.

Dean Forest.	Stafford-shire; Frog-hall.	North-ampton-shire.	Dean Forest.	Belfast.	North-ampton-shire.
Dick.		Riley.	Dick.	Tookey.	Riley.
32·76	52·83	50·53	48·99	35·91	34·41
. .	. .	trace	0·24	6·57	trace
trace	0·81	0·51	0·16	0·05	0·27
0·05	. .	7·52	0·17	27·95	6·40
0·25	14·61	11·92	14·07	0·60	25·72
0·25	5·70	0·62	10·21	0·20	0·87
. .	. .	0·11	. .	0·49	
33·52	trace	8·80	0·79	9·75	6·69
. .	18·14	7·98	20·75	. .	18·45
0·0 9	0·32	1·28	0·06	. .	1·47
trace	0·28	. .	trace	. .	0·07
. .	. .	0·17	. .	. .	0·30
3·55	4·75	11·00	5·18	18·60	6·97
. .	1·30				
00·47	98·74	100·44	100·62	100·12	101·62
22·93	36·98	35·37	34·46	30·25	24·09

ore; Spatheisenstein; fer spathique.—This bonate, and in its purest state contains 48·27 line, sometimes presenting distinct crystals ibrous nodular masses known by the name of white to yellow or brown, and is very often nplete conversion into hydrated ferric oxide n. Spathic iron ore occurs as veins and beds nestone strata. It is worked in this country the Continent it is of more frequent occur- and Westphalia, where it constitutes entire er the name of "steel ore" for yielding very

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Spathic iron ore generally contains a considerable amount of manganese and small quantities of lime and magnesia, and is sometimes associated with lead and copper ores, quartz, fluor-spar, calcspar, heavy spar, &c., but is frequently quite free from any admixture of impurities that would be prejudicial to the iron made from it.

Analyses of Spathic Iron Ore.

Source	Müsen, Westphalia.	Ripsey Vein. Durham.	Weardale. Durham.	Brendon, Somersetshire.		Siegen Alte Birke.	Ehrenfriedersdorf; Saxony.	Exmoor; Devon.
Analyst	Peters.	Dick.	Tookey.	Spiller.	Price & Nicholson.	Schnabel.	Magnus.	Spiller.
Ferric oxide	2·75	. .	0·81	0·81	. .	. .	. .	0·07
Ferrous oxide	. .	49·47	49·77	43·84	43·94	43·59	36·81	17 91
Manganous oxide	0·83	2·42	1·93	12·64	12·88	17·87	25·31	7·64
Zinc oxide	0·04							
Alumina	1·63	0·06	. .	0·01				
Lime	1·75	3·47	3·96	0·28	. .	0·88	. .	24·80
Magnesia	2·29	3·15	2·83	3·63	4·00	0·24	. .	6·17
Silica	1·62	4·93	3·12	0·07				
Carbonic acid	39·92	37·71	37·20	38·86	39·18	38·22	38·35	41·75
Phosphoric acid	0·54	trace	trace	. .	. .	. .	. .	trace
Sulphuric acid	. .	trace						
Iron pyrites	0·22	. .	0·04	. .	. .	. .	. .	0·11
Water { hygroscopic / combined	0·45	. .	0·30	0·18	. .	. .	. .	0·38
Organised substance	0·39	trace						
	100·55	101·29	99·96	100·32	100·00	100·00	100·47	99·23
Percentage of iron	42·59	38·56	38·95	34·67	34·18	33·90	28·63	13·98

Ferrous carbonate mixed with clay often occurs with beds of coal, in sedimentary rocks, and is known under the name of argillaceous, sphærosiderite, or clay iron ore. It is compact and earthy; of various shades of grey and brown, or sometimes quite black, owing to an admixture of carbonaceous substance, and occurs in lenticular masses or nodules. This ore is generally very abundant in the coal measures; but in some instances it is almost wholly wanting in those rocks, as for instance in the coal fields of Northumberland, Durham, Lancashire, and Belgium. The principal localities where it is worked in this country are the coal fields of Scotland, Staffordshire, Shropshire and Wales.

It is found to some extent in France and Germany, and abundantly in America, but is not worked there.

Analyses of Clay Iron Ore from the Coal Measures.

Name of ore	Scotland.							
	Black band.							
Analyst	Colquhoun.							
Ferric oxide	. .	0·33	1·16	0·23	0·47	1·16	0·23	2·72
Ferrous oxide	45·84	38·80	35·22	53·03	43·73	35·22	53·82	40·77
Manganous oxide	020	0·07						
Alumina	2·53	6·20	5·34	0·63	5·13	5·34		
Lime	1·90	5·30	8·62	3·38	2·10	8·62	1·51	0·90
Magnesia	5·90	6·70	5·19	1·77	2·77	5·19	0·28	0·72
Silica	7·83	10·87	9·56	1·40	9·70	9·56	2·00	10·10
Carbonic acid	33.63	30·76	32·53	35·17	32·24	32·53	34·39	26·41
Sulphur	. .	0·16	0·62	. .	0·20	0·62		
Water { hygroscopic / combined	. .	. .	. .	. .	. .	. .	. .	1·00
Organic substance	1·86	1·87	2·13	3·63	1·50	2·13	7·70	17·38
	100·37	101·00	100·37	. .	99·66	100·37	100·00	100 00
Percentage of iron	28·40	30·00	28·40	40·90	34·00	28·40	41·60	34·60

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10 to 15 or even 30 per cent. of coaly substance,
es of Scotland, and some parts of England and
" "black band."

rom the Coal Measures—continued.

e.	Derbyshire.			Staffordshire.	
Black mine; gate.	Brown Rake; Butterley.	Dalemoor Rake; Stanton.	Dog-tooth; Staveley	Chalky mine; Foley.	Red Shag; Shelton.
Spiller.				Dick.	
2·39	1·49	3·49	1·42	0·12	0·05
41·77	37·99	39·55	28·27	51·07	46·53
1·13	1·51	1·50	1·02	2·36	2·54
4·79	5·57	5·45	2·21	2·47	1·22
2·55	4·59	3·38	13·94	1·74	2·44
3·85	3·37	2·88	9·27	1·10	1·39
0·43	0·55	0·48	0·16	0·28	20
8·93	10·04	10·22	3·55	3·02	1·93
31·39	29·92	28·63	37·61	33·63	30·77
0·75	0·80	1·12	0·74	1·12	0·69
trace	trace	trace	trace	trace	0·04
. .	0·06	0·05	0·04	0·17	0·34
0·55	0·74	0·51	0·18	0·99	
1·15	1·47	1·24	0·73		1·47
0·86	1·42	1·14	0·92	1·24	10·46
100·54	99·52	100·14	100·16	98·97	100·07
34·16	30·60	33·20	22·98	39·88	36·39

rom the Coal Measures—continued.

Staffordshire.					
Dudley.			Bunker's Hill.	Darlaston.	
Gubbin.	Whitestone.	Binds.	Balls.	Whitestone.	Gubbin.
	Spiller.		Dick.	Tookey.	
0·40	0·04	1·15	0·43	3·17	3·82
45·86	48·63	30·96	52·04	33·92	49·40
0·96	1·29	0·73	0·92	0 77	0·86
5·86	3·64	9·58	4·98	6·44	3·05
1·37	4·45	1·84	0·53	2·65	0 86
1·85	0·80	3·11	1·18	4 43	0·52
. .	0·11	0·74	0·32	0·74	0·30
10·88	6·21	26·50	6·63	18·23	6·22
31·02	32·16	22·13	32·31	26 89	32·05
0·21	0·31	0·26	0·21	0·35	0·23
trace	0·06	trace	trace		
. .	. .	. .	. .	. .	1·27
0·10	0·16	0·12	0·13	0·15	0·13
1·08	0·32	0·56	0·46	0·42	0·37
	1·23	1·83		0·98	0·29
0·90	0·28	0·10	0·51	0·47	0·54
100·29	99·69	99·61	100·25	99·61	99·81
35·99	37·45	24·88	40·84	28·87	41·06

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Analyses of Clay Iron Ore from the Coal Measures—continued.

Source	South Wales.							
	Ponty-pool.	Blaen-avon.	Cwm Avon.	Aberdare.		Aber-carn.	Llanelly.	
Name of ore	Balls.	Black pin.	Sulphury mine.	Coal brass.		Black band.	raw.	calcined.
Analyst	Riley.	Dick.		Price & Nicholson.		Ratcliffe	Price.	
Ferric oxide	0·50	0·45	0·34	. .	. .	4·10	. .	80·00
Ferrous oxide	44·50	41·22	40·30	37·07	42·64	43·37	43·30	
Manganous oxide	0·73	1·07	1·03	0·23	0·26	1·50	1·08	1·80
Manganic oxide	. .	. .	. .	. .	. .		. .	
Lime	2·05	2·89	1·44	6·61	5·24	3·00	1·26	2·10
Magnesia	3·26	3·68	2·94	7·40	5·26	0·25	2·67	4·45
Soda	0·13							
Potash	. .	0·48	0·82	. .	. .	0·32		
Alumina	5·95	4·88	7·90	. .	. .	6·5		
Clay	. .	. .	. .	2·70				
Silica	10·81	11·60	14·43	. .	. .	·80	7·20	10·61
Carbonic acid	30·92	30·07	28·23	37·14	36·89	30·50	28·46	
Phosphoric acid	0·23	0·76	. .	0·23	0·17	trace	0·67	1·03
Sulphuric acid	. .	trace	trace					
Sulphur	. .	. .	. .	. .	. .	1·56	0·26	
Iron pyrites	0·11	0·15	0·09	trace	0·22	. .		
Water hygroscopic	0·76	. .	0·74	. .	. .	0·27		
Water combined		1·21	. .	. .	. .	0·31		
Organic substance	0·21	0·82	0·29	9·80	8·87	6·25	15·10	
	100·24	99·28	99·43	100·18	99·55	100·28	100·00	99·99
Percentage of iron	34·96	32·44	31·63	28·88	33·17	36·4	33·68	56·00

Clay iron ore also occurs abundantly in strata belonging to the Lias, as well as in the Oolite and Tertiary series of rocks, sometimes partially or wholly converted into brown iron ore by atmospheric oxidation. This ore is now largely worked in the Cleveland district in Yorkshire.

Analyses of Clay Iron Ore from the Lias and Oolites.

Source	Middles-bro.	Hutton Low Cross.	Eston Nab.	Upleat-ham.	Belmont	Gros-mont.	Nor-manby.	North-amptonshire.
Analyst	Percy.	Crow-der.	Crow-der.	Crow-der.	Percy.	Percy.	Pattin-son.	Dick.
Ferric oxide	2·86	4·25	1·20	5·80	3·50	. .	2·60	3·31
Ferrous oxide	43·02	40·86	43·35	38·25	39·00	40 77	38·06	33·29
Manganous oxide	0·40	. .	. .	. .	1·30	0·67	0·74	1·11
Alumina	5·87	3·44	9·88	12·20	7·46	1·32	5·92	7·89
Zinc	5·14	3·80	0·58	5·00	7·44	4·08	7·77	0·50
Magnesia	5·21	3·70	5·35	2·40	3·82	5·34	4·16	11·77
Potash	. .	. .	. .	. .	. .	. .	. .	0·20
Silica	7·17	7·20	7·65	7·45	9·46	8·80	10·36	19·49
Carbonic acid	25·50	32·50	22·96	25·40	23·06	31·80	22·00	24·79
Phosphoric acid	1·81	0·96	3·87	0·50	1·60	0·06	1·07	0·22
Sulphuric acid	. .	0·30	. .	trace	. .	. .	trace	trace
Iron pyrites	. .	1·60	0·09	trace	. .	. .	0·14	0·13
Water hygroscopic	0·34	1·45	5·07	3·00	3·66	2·70	4·45	. .
Water combined	3·14							0·54
Organic substance	0·15	. .	. .	. .	. .	. .	. .	0·08
	100·61	100·06	100·00	100·00	100·30	99·10	97·27	100·32
Percentage of iron	35·46	34·75	34·54	33·81	32·78	31·71	31·42	28·28

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Both clay iron ore and carbonaceous iron ore are frequently accompanied by admixtures of metalliferous, sulphuretted, arsenical, and phosphatic minerals, sometimes in such amount as to detract from their value for smelting purposes; but generally they are sufficiently pure to furnish iron of good quality. Some kinds of the ore known as "coal brass" also contain a considerable amount of ferrous carbonate, though they were disregarded as iron ores, until attention was directed to their composition in 1853 by Messrs. Price and Nicholson.

Native iron Sulphides occur very frequently and in great abundance in some places. Of late years these minerals have been much used as a source of sulphur, and are largely imported from Spain and Norway for that purpose. The principal varieties are:

1. *Iron pyrites* (*Eisenkies; pyrite*), which has a yellow colour and metallic lustre. Specific gravity 4·9 to 5·1. It occurs crystalline, granular and compact, frequently disseminated through other minerals. In its purest state it contains 53·33 per cent. iron, and 46·67 per cent. sulphur.

Analyses of Iron Pyrites.

Analyst	Pattinson.							Price & Nicholson.	Clapham.
Source	Spain.		Belgium.	Westphalia.	Norway.	Ireland.	Coal brasses.	Wales.	Cornwall.
Iron	38·70	41·41	39·68	38·22	39·22	40·52	31·44	49·72	32·20
Sulphur	44·60	49·30	45·01	45·60	45·50	44·20	38·10		34·34
Copper	3·80	5·81	. .	. .	1·80	0·90	trace	. .	0·80
Lead	0·58	0·66	0·37	0·64	. .	1·50	. .	. .	0·40
Zinc	0·30	trace	1·80	6·00	1·18	3·51	. .	. .	1·32
Thallium	trace	trace	trace	trace					
Ferrous oxide	. .	. .	. .	. .	. .	. .	. .	11·01	
Lime	0·14	0·14	0·25	0·11	2·10	0·24	4·96	7·95	
Magnesia	trace	trace	. .	. .	0·01	. .	0·33	5·74	
Carbonic acid	. .	. .	. .	. .	1·65	. .	5·11	19·29	
Arsenic	0·26	0·31	trace	trace	. .	0·33	trace	. .	0·91
Oxygen	0·23	0·25	0·42	0·37	0·45	0·25	0·31		
Coaly substance	. .	. .	. .	. .	. .	. .	14·45	6·10	
Gangue	11·10	2·00	12·23	8·70	9·08	8·80	1·40	. .	29·0
Moisture	0·17	0·05	0·25	0·36	0·17	0·90	0·90		
	99·88	99·93	99·91	100·30	100·16	100·34	100·30	99·81	98·98

2. *White iron pyrites* (*Strahlkies*; *pyrene*), is a variety of iron pyrites of a white colour; it is also of frequent occurrence.

3. *Magnetic pyrites* (*Magnetkies; pyrite magnetique*), has a bronze colour with metallic lustre, and is slightly magnetic. Specific gravity 4·5 to 4·7. It occurs both crystalline or granular, and compact. In its purest state it contains 60·49 per cent. iron, and 39·51 per cent. sulphur.

4. *Arsenical pyrites* (*Mispickel; Arsenkies; fer arsenical*), has a steel grey colour, and metallic lustre. Specific gravity 6 to 6·2. It occurs in the same states as iron pyrites, frequently associated with tin ores, and contains 34·35 per cent. iron, 10·96 per cent. sulphur, and 56·79 arsenic. This mineral frequently contains a considerable amount of silver. Both it and the other varieties of iron pyrites sometimes contain gold, and varying proportions of other metallic sulphides, especially copper pyrites, with which they are frequently associated.

The residue left after separating sulphur from iron pyrites by roasting, is smelted to extract the copper it contains; and attempts are being made to use it also for obtaining the iron from it.

Of other native compounds of iron that occur in large quantities, the most important are the *chromate* (see CHROME IRON ORE, i. 939); the *titanates iserine*, and *ilmenite* (see TITANATES); the *tungstate* (see WOLFRAM); the *silicates* (see GREEN EARTH, ii. 944, and SILICATES); the *ferrous* and *ferric phosphates*. (See PHOSPHATES.)

Preparation.—1. Pure iron may be obtained by heating pure ferric oxide in a current of hydrogen gas. If the reduction be effected at the lowest possible temperature, the iron is obtained in the state of a grey powder which is pyrophoric, and takes fire on contact with atmospheric air, being converted into ferric oxide. At a strong red heat the metal is obtained in a spongy state and is less readily oxidised.

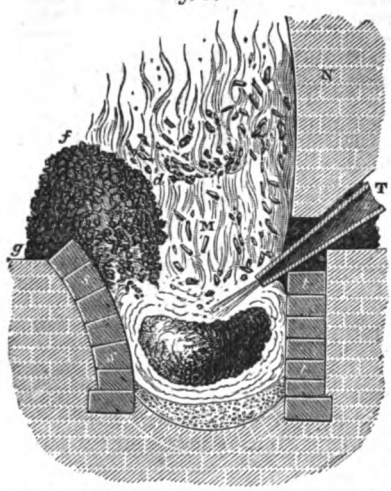
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2. A mixture of iron wire or iron filings, with one-fourth part of magnetic placed in a closely covered crucible, under a layer of powdered glass, free from metallic oxides, and exposed to a white heat in a smith's forge, yields a button containing only mere traces of carbon or other impurities.

Manufacture on the large scale.—Malleable iron may be obtained directly fr ores by heating them with charcoal under the influence of a blast of air. Fo malleable iron was obtained by this method exclusively, but it is now practised only in Sardinia, the Pyrenees, India, some parts of America, Africa, and other c where metallurgic art is less advanced than in the great iron-producing dist Europe.

1. *Production of malleable iron direct from the ore.*—This is chiefly practi cording to what is termed the Catalan method. It consists in heating the ore with a charcoal fire urged by a blast, and in a manner very similar in its character, to that adopted in working a smith's forge. The most importan several arrangements for this operation, comprised collectively under the term " ery " (*Luppenfeuer, forge Catalan*), is the *hearth* (*Heerd; creuset*), which is cubical chamber built of stone, and lined with blocks of iron, *s*, *s*, *t*, *t*, at t and front. It is placed against a wall N, N, through which the tuyere, T blowing machine projects, as shown in *fig.* 573. The ore to be reduced is broken the size of a nut, and is placed aga front of the hearth, *s*, *s*, while the ing space M, between it and the *t*, is filled with charcoal, and w hearth is filled in this way, the up of the heap of ore forms a ridge a the surface *f g*, being covered with of closely packed charcoal dust (*d* The fire is then urged by the blast ore becomes gradually deoxidise the gangue or earthy substance c in the ore, combines with a portio rous oxide, forming a fusible silice which collects at the bottom of the Fresh charcoal, and the finely divi are constantly supplied to the fir while, and eventually the de mineral sinks down, in the state c able iron, to the bottom of the where a workman kneads toget fragments into a spongy mass, v taken out of the fire, and render by hammering while still red-hot, unite the metallic particles, and it drawn out into bars under a forge h

Fig. 573.



Only the richer kinds of ore can be treated in this way, and it always i the waste of a large portion of the iron, which escapes reduction, and by into combination with the siliceous and earthy portions of the ore, forms consisting chiefly of ferrous silicate. In the extraction of iron by this method, th tion is effected, perhaps entirely, by carbonic oxide, and the carburation of the such an extent as to determine the production of cast iron, is prevented by the an adequately high temperature.

2. *Indirect process.*—The production of malleable iron is now for the mo effected by operating upon cast iron so as to deprive it of the greater part of the and silicon it contains, and at the same time to separate other admixtures tha be prejudicial to the quality of malleable iron. This operation is conducted ways, the one termed the charcoal finery, the other puddling. Both cons partial oxidisation of the cast iron, and production of a fusible ferrous silicate reacts upon the carburet of iron and determines the oxidation of the greater the carbon and other substances contained in the cast iron.

The main distinction between these two modes of operating is that, in the c charcoal is employed in contact with the cast iron; while, in the other, coal is a reverberatory furnace, so that the iron is acted upon in a separate chamber actual contact with the fuel, but only by the flame and heated gases produced combustion.

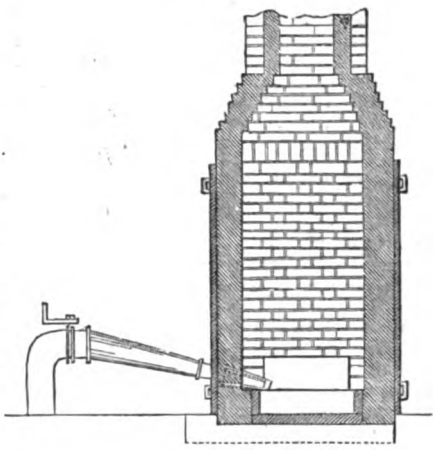
White cast iron containing a small amount of carbon is most suitable for con into malleable iron, because it does not melt so readily at a moderate heat and so liquid when melted as grey cast iron, but softens before melting and rema

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some length of time in a viscous condition, which admits of its presenting a greater surface to the action of oxidising agents when stirred about. Its carbon is also more easily oxidised than the graphite of grey cast iron. When therefore grey cast iron has to be converted into malleable iron, it is in the first instance converted into white iron by a preliminary melting in the running-out fire (p. 349).

The production of malleable iron by the charcoal-finery, is practised in different places with a great number of minute variations, determined partly by the nature of the pig iron operated upon, partly by less important circumstances.

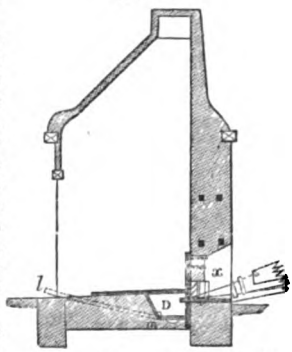
Fig. 574.



The charcoal-finery employed in Wales, and some other parts of the country, for manufacturing the sheet iron used for tin plates, which requires to be of very good quality, is represented in section by *fig.* 574. It consists of a quadrangular hearth lined with cast iron plates enclosed within brick walls and furnished with a blast apparatus. About 2 cwt. of pig iron, melted with coke in a similar kind of hearth, called a *melting finery*, is run into the hearth, covered with charcoal and stirred about, while the fire is urged by a blast of air until the iron becomes sufficiently decarburised to be malleable. Then it is collected in a *lump* (*Luppe; loupe*) at the end of an iron bar, and removed from the hearth for the purpose of being hammered into a prismatic slab about 2 inches thick. This is broken into pieces of about 25 lbs. each, called *stamps* (*schirbel; lopins*). About three of these stamps are piled upon the flattened end of an iron bar termed the *staff* or *portal*, and raised to a welding heat in a kind of reverberatory furnace termed the *hollow fire*, and again hammered into a slab about 3 inches thick, which is passed between rollers until it forms a sheet of the requisite thickness.

In Sweden the greater part of the best iron is made in a very similar manner, except that there, as well as in Germany and other parts of the Continent, the pig iron is melted in the same hearth in which it is converted into malleable iron. An ordinary form of the hearth employed is represented by *fig.* 575.

Fig. 575.



The pig iron is melted above the tuyere, so that it may not be exposed to the blast until it has become liquid, and the blast is regulated so as to retain the metal on the hearth in a proper state of fusion; the blast is then stopped, the slag run off, the iron raised off the hearth, and placed on the top of a fresh supply of charcoal, after which it is again melted. When the decarburation has advanced far enough, which may be judged of by the consistence of the metal, it is again raised up, covered with charcoal, subjected to a strong welding heat to melt away the slag, and then hammered out to a short bar, which is cut into pieces that are again welded together, and drawn out into bars under a hammer.

In order to appreciate the chemical nature of the process that takes place in the charcoal-finery, it is necessary to consider the composition of the slags. They consist essentially of silica and ferrous oxide, but may be divided into two classes, viz. poor slag (*Rohschlacke*) and rich slag (*Gaarschlacke*).

The poor slag is formed during the first melting of the pig iron and the earlier stage of the operation. It consists essentially of ferrous silicate. It is very liquid and solidifies rapidly, is of a blackish-grey colour with metallic lustre, crystalline, frequently variegated, and sometimes porous. The crystals have the form of olivine or iron chrysolite, and the composition of the slag approximates to that of this mineral.

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Analyses of poor Slags from the Charcoal-finery.

Source	. .	. .	. .	Magdesprung.
Analyst	Mitscherlich.	Rammelsberg.	Walchner.	Wiegand.
Ferric oxide . .	. .	2·25		
Ferrous oxide . .	67·24	63·51	62·04	57·3
Manganous oxide .	. .	. .	2·64	4·5
Magnesia . . .	0·65	. .	1·40	
Lime . . .	. .	. .	. .	2·8
Alumina . . .	. .	. .	. .	3·0
Potash . . .	. .	. .	0·28	
Silica . . .	31·16	34·38	32·34	32·4
	99·05	100·14	99·70	100·0
Ratio of oxygen in bases to oxygen in silica . .	·914	·822	·868	·907
Percentage of iron .	52·30	50·69	48·25	44·95

The rich slag is formed during the latter stage of the operation. It is less liquid, and solidifies less quickly than the poor slag. It forms an agglutinated mass; is heavier, of a grey colour, and has a compact fracture. Its composition varies much, and the amount of iron is greatest in that formed at the end of the operation.

In the charcoal-finery process, the separation of the carbon, silicon, phosphorus, and manganese from pig iron is effected by the oxidation of these substances, partly by the blast and partly by the ferrous oxide contained in the slag, formed at the end of the operation.

Cast iron melted with ferric oxide yields carbonic oxide and iron. Iron containing silicon, when heated with iron oxides, yields ferrous silicate. The ferrous silicate constituting poor slag is not reduced, either by pig iron or by carbon, at a red heat; it is only at a very high temperature that there is a reaction between the carbon and ferrous oxide, with elimination of iron. The more highly basic ferrous silicates, constituting rich

Analyses of rich Slag from the Charcoal-finery.

Name of works	Sweden.		Lauch-hammer.	Sauvigny.	Norway.	Rybnik.	
	Gysinge.	Skebo.				Silesia.	
Analyst . .	Winckler.	Sefström.	Lampadius	Berthier.	Ström.	Karsten.	Hoffmann.
Ferric oxide .	. .	. .	. .	. .	. .	. .	6·00
Ferrous oxide .	82·9	82·1	77·00	74·0	71·3	61·2	71·15
Manganous oxide .	. .	6·8	3·00	3·6	. .	6·7	
Magnesia . .	carbon and loss 3·2	2·8	. .	. .	2·7	2·4	0·46
Lime . . .		. .	1·75	1·8	. .	0·9	1·26
Alumina . .		. .	3·00	1·2	. .	0·2	
Potash . .							
Silica . . .	13·9	7·6	10·25	19·8	21·4	18·1	21·01
Phosphoric acid .	. .	. .	1·75	. .	3·7		
	100·0	99·3	99·75	100·4	99·1	99·5	99·88
Ratio of oxygen in bases to oxygen in silica . .	2·485	5·150	3·598	1·736	1·418	1·7	1·663
Percentage of iron	64·48	63·86	59·89	57·56	55·46	47·6	59·50

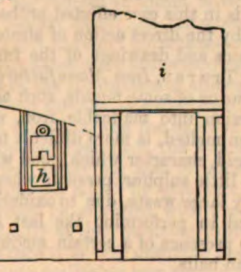
slag, on the contrary, are decomposed, even at a red heat, by pig iron, in such a manner that the excess of ferrous oxide is reduced, and a less basic ferrous silicate remains.

During the first stage of the process, the silicon of the iron, together with the oxidised iron, and any sand that may be present, contribute to the formation of poor slag; but as the oxidation of the iron continues, the slag gradually becomes richer in iron, and serves to a great extent as the medium by which the action of atmospheric oxygen upon the pig iron is exercised. Phosphoric acid and manganese also pass into the slag. The conversion of pig iron in this way must not be carried on too rapidly,

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pure varieties, or the oxidation of the silicon, phos-
separation, will not be fully effected; nor must it be
ld be unnecessary waste of iron by oxidation.
in the charcoal-finery; but since the object of that
a high temperature as to separate all the impurities
e so much heated as in other cases.
nmöfen; affinage à la houille.—This is at the present
method of manufacturing malleable iron, especially
ence between the operation of puddling and that of
the use of a reverberatory furnace for the purpose, in
he iron may be effected in a chamber separated by a
e where the fuel is burnt. The metal is thus kept
uel by which the furnace is heated, and it is acted
s passing over the bridge into the working chamber.
e use of mineral fuel in place of charcoal, and is
g the iron from becoming contaminated with the im-
fuel in far larger amount than in wood charcoal.
furnace is represented by *fig.* 576 in elevation, and by
orizontal sections. It is built of brick, and cased with
strong plates of cast iron,
held together by iron
bars. The fireplace is
shown in the sections at
b b, and the firing hole at
a in the elevation; *c* is
the bridge separating the
fireplace from the work-
ing chamber *f*; *d d* the
bed or hearth upon which
the cast iron is melted
and decarburised. This
is now constructed of
cast-iron plates covered
with a layer of red iron
ore, or some material

6.



le. The working door *g* has a small hole at the bottom,
about the metal in the furnace. Just below this
hearth, is a small hole called the floss or tap-hole,
d through which the slag is run out from the hearth.
run away from a hole *k* below the chimney. The

Fig. 577.

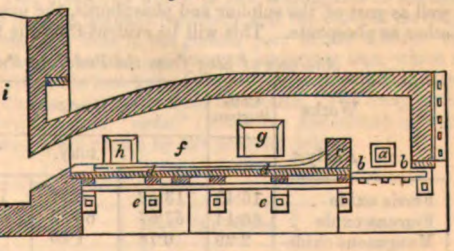
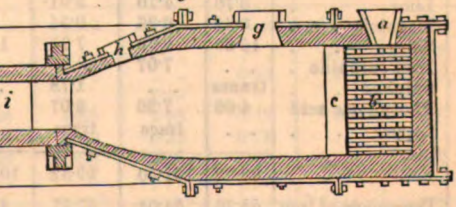


Fig. 578.

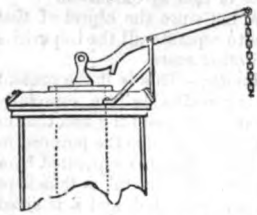


then increased, and soon after the whole of the metal

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is melted, it begins to swell and heave as if boiling, while jets of blue flame issue fro

Fig. 579.



all parts of the mass. This is due to the formation carbonic oxide by the reaction of the carbon in t metal with the ferruginous oxides present. As this r action progresses, the iron becomes pasty, and in co sequence of the oxidation of the silicon contained the iron, and the formation of ferrous silicate, a liqu slag separates from it, and collects round the metal the hearth, or flows away towards the floss *k*. Wh the separation of carbon from the metal has advanc to some considerable extent, the oxidising action the atmosphere in the working chamber is lessened lowering the damper and keeping the iron surround by highly carbonaceous or smoky gas. When the iron has become so far decarb rised as to be malleable, or as it is termed "come to nature," it is gathered together a worked into several lumps with an iron bar, ready to be removed from the furnace.

A modified form of this operation is adopted at some works, under the name of "pi boiling." The furnace used for this purpose is constructed much in the same way the puddling furnace, except that for "pig-boiling" the hearth is much deeper a more pan-shaped than in the puddling furnace. The hearth is also covered with thick layer of red iron ore, or roasted slag from the puddling furnace, and the deca buration of the pig iron is in this case effected probably more by the action of oxidis compounds of iron than by the direct action of atmospheric oxygen.

For detailed descriptions and drawings of the furnaces and machinery used in th manufacture of iron, see Truran, *Iron Manufactures of Great Britain*, London, 186

The presence of sulphur or of some metals, such as zinc, lead, and copper in the p iron, retards the conversion into malleable iron, and in the case of pig iron th becomes very liquid when melted, is more difficult to bring it into a plastic conditi than when it has the viscid character which good white cast iron, containing a sma amount of carbon and a little sulphur, presents when melted. In puddling sulphu iron, there may be a very large waste, due to oxidation of the metal, in consequence the greater time occupied in performing the last stage of the operation. It is th opinion of some that the presence of a certain amount of phosphorus in sulphury iro facilitates its working into balls.

The reactions that take place in puddling are essentially the same as those whic take place in the charcoal refinery. Under the influence of the free oxygen in th atmosphere of the working chamber, a portion of the iron is oxidised, and at the sam time the manganese, silicon, carbon, sulphur, and phosphorus present in the iron, a also oxidised, either by the direct action of air, or through the medium of the metall oxides added to the pig iron, or formed during the process, the result being the pr duction of a slag or cinder, consisting of ferrous and manganous silicates, and magnet oxide, and containing the other earthy impurities present in the iron operated upon, well as part of the sulphur and phosphorus, the one probably in state of sulphide, th other as phosphate. This will be evident from the following analyses of these slags.

Analyses of Slag from the Puddling Furnace, "Tap Cinder."

Works	Chillington.	Dowlais.		Broomsgrove.	Bromford.	Wales
Analyst		Riley.		Percy.		Noad.
Ferric oxide .	16·42	13·53	8·27	17·00	23·75	17·11	
Ferrous oxide .	60·14	57·67	66·32	58·67	39·83	48·43	70·48
Manganous oxide	2·29	0·78	1·29	0·57	6·17	1·13	12·80
Alumina . .	trace	1·88	1·63	2·84	0·91	1·28	
Lime . .	0·70	4·70	3·91	2·88	0·28	0·47	
Magnesia . .	0·42	0·26	0·34	0·29	0·24	0·35	
Silica . .	15·30	8·32	7·71	11·76	23·86	29·60	8·24
Iron sulphide .	. .	**7·07**	. .	**3·11**	**0·62**	**1·61**	
Sulphur . .	**traces**	. .	**1·78**	. .	. .	. .	**0·53**
Phosphoric acid	**4·66**	**7·29**	**8·07**	**4·27**	**6·42**	**1·34**	**7·66**
Copper . .	. .	trace	trace				
	99·93	101·50	99·32	101·39	102·08	101·32	99·71
Percentage of iron	58·26	58·04	57·37	47·61	47·60	44·22	54·81

The elimination of sulphur and phosphorus from pig iron appears to be alway

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ed with oxidation of the iron in a degree proportionate to the quantity of those nces separated from the metal. Consequently, in order that the waste of metal curred in producing malleable iron of good quality may not exceed such a limit ld be tolerable in practice, it is essential that the amount of those substances pig iron operated upon should not be large. The smaller the amount of r and phosphorus in the pig iron, the easier is its conversion into good mal- ron, and so far as the separation of those substances is concerned, the smaller waste experienced in this operation.

manganese present in pig iron appears to be always separated almost entirely manufacture of malleable iron. The presence of manganese in pig iron appears cise, in some way not fully understood, a beneficial influence upon the quality nalleable iron made from it by the operation of puddling. Experiments recently y Caron (Compt. rend. xlvi. 828) appear to show that sulphur may be sepa- rom pig iron by the influence of manganese during the decarbonisation, but that orus is not separable in the same way. He operated upon iron containing 1·15 t. of sulphur. By melting it three times without any admixture, the amount hur was reduced to 0·96 per cent; but by adding to it 6 per cent. metallic nese, and by melting three times with access of air, the amount of sulphur was l to 0·8 per cent. The same iron melted with 10 per cent. ferric oxide showed a on in the amount of sulphur from 1·15 to 1·08 per cent., and by melting it with 10 t. ferric oxide and 6 per cent. manganese, the sulphur was reduced to 0·07 per cent.

separation of silicon from pig iron in puddling, as in other modes of producing ble iron, takes place very readily under the influence of oxidising conditions, rmation of ferrous silicate; and the chief importance attaching to its presence in n employed for that purpose, relates more to the amount of malleable iron obtain- an to any special difficulty in the elimination of silicon. In the ferrous silicate ating the slag of the puddling furnace, there is three and a half times as much silicon; so that, if both the silica and the oxide of iron it contains originate he oxidation of the pig iron operated upon, the waste of iron will be very con- le when the amount of silicon in the pig iron is large. Under the supposition e slag is derived wholly from the metal by oxidation, the puddling of pig iron ning 5 per cent. of silicon would be attended with a waste of 15 per cent. of iron this cause alone, independently of that resulting from the separation of carbon, and other substances. Hence it is very desirable that the amount of silicon in n intended for conversion into malleable iron should not be large.

nat modification of the method of producing malleable iron known as "boiling," iron does not undergo any preliminary treatment, and the furnace is sometimes d with the liquid metal run direct from the smelting furnace, so as to save the quisite for remelting it. But in puddling, the practice is generally to submit the n beforehand to an operation known as *refining* (*Feinen; mazéage*), which con- melting the pig iron, in contact with coke and with the aid of an air-blast, in h similar to a charcoal finery, but larger, and termed a *refinery* or *running-out einheerd; feu de finerie*). This operation, which, in fact, corresponds to the first g of the pig iron under the blast in the charcoal-finery, has the effect of partially onising the iron, and of removing from it the greater part of the silicon. At ne time grey pig iron is brought into the condition of white cast iron, which is uitable for conversion into malleable iron by puddling. This change is facilitated denly cooling the metal with water as it runs from the hearth. The composition ed iron, or, as it is technically termed "*metal*" (*Feinesen; fine-metal*), and the that takes place in the process, are shown by the analyses below.

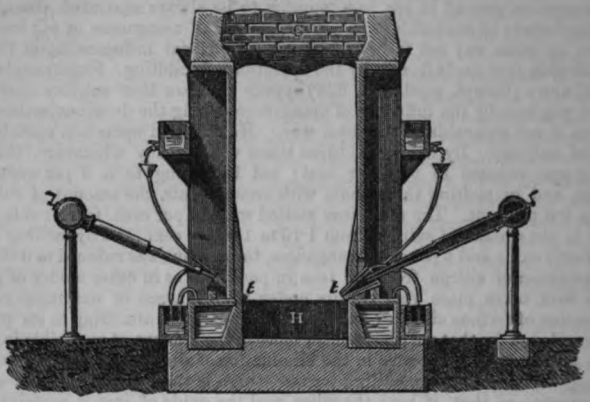
Analyses of Refined Iron.

Works .	Bromford.	Königshütte.		Ebbw Vale, Wales.		France.	
Analyst .	Dick.	Abel.		Noad.		Regnault.	
		pig iron.	*refined.*	*pig iron.*	*refined.*	*pig iron.*	*refined.*
. .	95·14	. .	. .	. .	. .	97·8	92·3
on . .	3·07	. .	. .	. .	0·30	1·7	3·0
				2·40			
n . .	0·63	4·66	0·62	2·68	0·32	0·5	4·5
ur .	0·16	0·04	0·30	0·22	0·18		
phorus .	0·73	0·56	0·50	0·13	0·09	. .	0·2
anese .	trace	. .	. .	0·86	0·24		
	100·17	100·00	100·00	100·00	100·00	100·00	100·00

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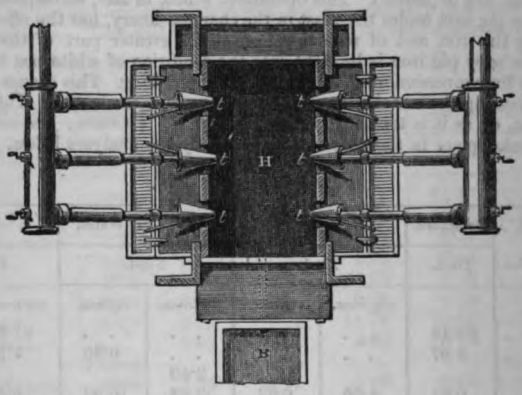
The refinery or running-out fire, represented by *fig.* 580, consists of a rectangular hearth H about 2 feet deep, and rather longer than it is wide. It is lined with cast-iron plates constructed so as to admit of being cooled by water circulating through them, and has three blast tuyeres *t*, *t* supplying hot air on each side. The chimney C is supported upon iron columns, and the spaces between them are closed with cast-iron plates. (See Truran, *op. cit.*, p. 193, *et seq.*)

Fig. 580.



A quantity of coke is put into the hearth, and after the fire has been sufficiently raised, about one or two tons of pig iron is placed on the top, covered with coke, and the fire urged by the blast until the whole of the metal has melted and run down into the hearth, where, under the oxidising influence of the blast, the carbon and silicon it contains are oxidised, and a slag is formed which floats on the surface of the metal. Fresh coke is added, meanwhile, and the heat kept up until the action has advanced sufficiently far. A hole level with the bottom of the hearth is then opened, and the melted metal run into a cast-iron mould B cooled externally by water; and a quantity of water is thrown upon it in order to cool it suddenly and to render the slag discharged from the hearth with it, more easily separable. Sometimes the charge of iron is run into the refinery direct from the blast furnace, and in some cases a quantity of

Fig. 581.



hammer-scale or the slag from previous operations, is added to the charge, in order to facilitate the process of purification by which the silicon and other impurities are separated.

The slag produced in the operation of refining is vitreous, dark-coloured, black or bluish. It consists essentially of ferrous silicate, and generally contains the greater

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some of the phosphorus and sulphur that were
n, together with the ash of the coke used as fuel.

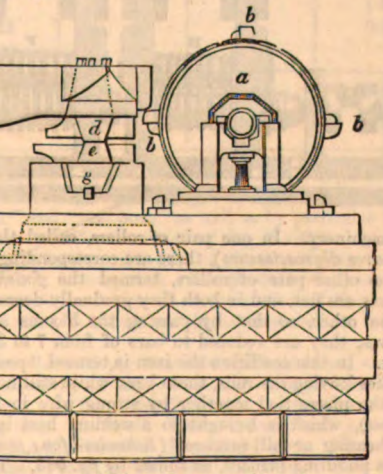
ses of Refinery Slag.

e.	Dowlais.		Bromford.
rg.	Riley.		Forbes.
	65·52	54·94	61·28
	1·57	2·71	3·58
	3·60	5·75	7·30
	0·45	1·19	3·41
	1·28	0·50	0·76
	25·77	33·33	22·76
	0·23	. .	0·46
	. .	0·17	
	1·37	0·99	
	. .	trace	
	99·79	99·68	99·55
	50·96	42·84	47·66

puddling depends very much on the kind of pig
hether it has been previously refined or not. Grey
he most considerable amount of silicon, afford a
than refined metal, the slag from which is propor-
being consequently less fusible, accumulates in
earth. It may also contain ferric oxide, in conse-
rous silicate, or of the ferrous oxide produced in
ilicate.

tained as above described are termed *puddle-balls*
rent spongy masses of malleable iron, intermixed
parate these admixtures and reduce the iron to
ddle-balls are removed from the working chamber
at a welding heat, and either hammered or
"shingling" or blooming.

Fig. 582.



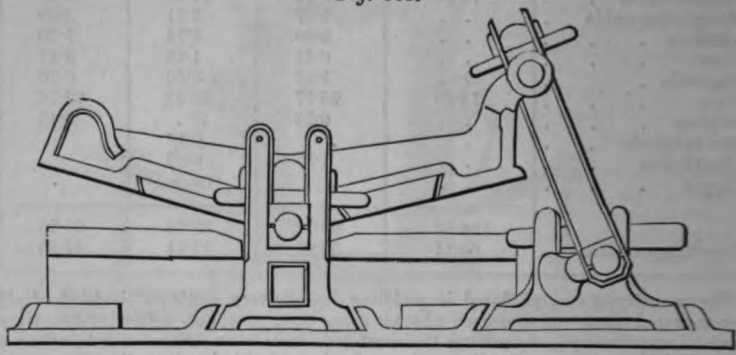
rpose, termed *forge hammers* (*Stirnhammer*; *mar-*
are either constructed of cast iron as shown at
the former a massive beam *c*, 8 or 10 feet long,
d having at the other end a ⊣ shaped head *d*, is

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lifted by the wipers *b*, *b*, *b* of the cam-wheel *a*, and, as that revolves, the hammer is let fall, at the rate of 70 or 80 strokes a minute, upon the anvil *c*, where the puddle-ball is placed. The *steam-hammer* (*Dampfhammer; marteau pilon*), consists of a block of iron, weighing several tons, attached to the piston of a steam-engine fixed above it, by which it may be lifted vertically in guides fitted to the frame work, and let fall upon the ball placed on an anvil.

The machines employed for compressing puddle-balls are of various forms, and are termed *squeezers* (*Quetscher; presse à charnière*). One of the most usual kinds, represented by *fig.* 583, consists of a lever, worked upon a fulcrum at the centre, by a crank

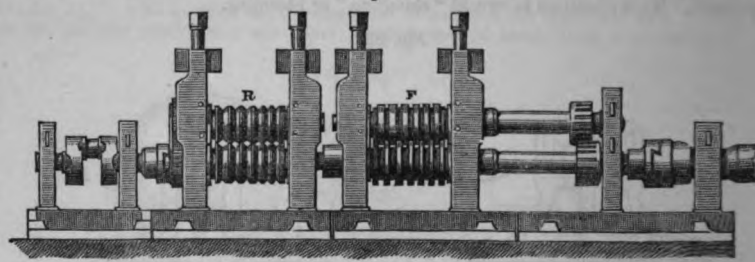
Fig. 583.



connected to one end, so that the jaws are alternately brought, at a rate of some 60 strokes a minute, nearer to the corresponding anvil-faces where the puddle-balls are placed to receive the pressure.

The puddle-ball, after having been hammered or squeezed, which occupies only a few seconds for each, is termed a *bloom* (*Luppe; loupe*), and is then drawn out into a bar by being rapidly passed several times, and while still red-hot, between grooved rollers, constituting what is termed a *forge-train* (*Streck-walzwerk, train de laminoir*), *fig.* 584. This consists of two pairs of rollers, R F, fitted in frames and driven

Fig. 584.



by machinery. In one pair of rollers, called the *roughing rolls* (*Cannelur-Walzen; cylindres dégrossisseurs*), there are corresponding V-shaped grooves round the surface. In the other pair of rollers, termed the *finishing rolls* (*cylindres finisseurs*), the grooves are flat, and in both they gradually decrease in size from one end of the rollers to the other, so that by passing the blooms successively through several pairs of grooves, they are reduced to bars of from 7 to 3 inches wide by from 1½ to ½ an inch thick. In this condition the iron is termed "puddle bar," or No. 1 iron.

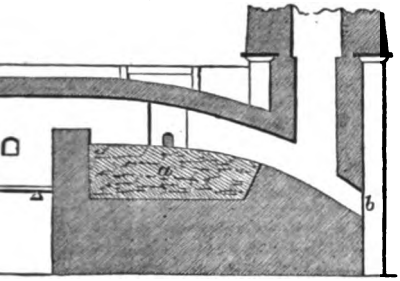
After leaving the rolls, these bars, while still hot, are cut into short lengths by shears and the pieces tied together by strong wire in a bundle is termed a *pile* (*Paket; trousse*), which is brought to a welding heat in a reverberatory furnace called the "re-heating or mill furnace" (*Schweiss-ofen; four de chaufferie*), constructed somewhat like a puddling furnace, as shown by *fig.* 585. The hearth *a* of this furnace, on which the iron is placed, is made of sand, and slopes down towards the flue, so that any slag that is formed may run down and escape at the hole *b*, leaving the hearth quite dry.

The piles are raised as rapidly as possible to a full welding heat in the mill furnace,

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then removed with tongs to mill-rolls, of a similar kind to those already de- but more highly finished, and drawn into bars which are again cut up, piled,

Fig. 585.



and then submitted to the same operations of heating and rolling several times, according to the required quality of the iron. Sometimes, after the first rolling of the iron into puddle bars, hammering is substituted in the place of drawing out between rollers. It is in this series of operations that the iron acquires its texture, and that close, uniform, and continuous fibre, upon which its strength and general good quality is considered to be chiefly dependent. The mode in which the pieces of iron are

l in the piles is considered to be of great importance as regards the result ; but notwithstanding the strong opinions expressed on this subject, little is s to the rationale of the connection apparently existing between the quality of and the mode in which it is wrought.

tain proportion of slag is produced during the reheating of the piles in the mill- which has a composition very similar to that of the slag from the puddling but the silica it contains is derived mainly from the sand forming the hearth.

Analyses of Mill-furnace Slag.

Works .	Dowlais.	Wasseralfingen.	Sweden.	
Analyst .	Riley.	Rammelsberg.	Dugendt.	Noad.
oxide . . .	. .	8·49	. .	5·00
s oxide . .	66·01	55·36	65·83	52·20
nous oxide . .	0·19	. .	0·74	
a . . .	2·47	. .	. .	9·60
. . . .	0·81	0·36		
ia . . .	0·27	trace		
. . . .	28·71	34·00	33·47	32·00
r . . .	0·11			
lphide . .	. .	. .	. .	1·95
oric acid . .	1·22	. .	. .	0·25
. . . .	trace			
	99·79	98·21	100·04	100·00
tage of iron .	51·34	49·0	51·20	45·34

all these successive operations have been completed, the iron is in the condition s "merchant iron," and the different degrees of quality are indicated as No. 2, c., or as "common," "best" and "best best," as well as by particular brands. es the waste of iron resulting from the formation of slag in refining, puddling, re is always a further waste due to the oxidation of the iron during the shin- ammering and rolling to which it is subjected. The product of this oxidation chiefly of magnetic oxide, which forms a crust on the surface of the hot iron, s off in scales, constituting what is known as "hammer-scale" or *mill-scale erschlag; battitures de fer*).

otal waste of iron in the conversion of pig iron into malleable iron, varies ac- to the kind of pig iron operated upon, and the amount of impurities in it, as upon the skill of the workmen. In South Staffordshire, the waste amounts to to 22 per cent. on the pig iron. In South Wales it sometimes amounts to to 28·5 per cent., though it is sometimes less than 13 per cent. Formerly the mounted in some cases to from 34 to 35 per cent. (Truran, *op. cit.* p. 215). The ction of iron bottoms for puddling furnaces, in place of sand, has contributed to reduce the waste of iron due to the formation of slag, and the use of ls containing ferrous or ferric oxides, as admixtures in the puddling or boiling n, in all probability tends to compensate the waste that would result from

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atmospheric oxidation, inasmuch as the oxidation effected by these admixtures would be accompanied by an equivalent elimination of metal from them.

The greater part of this waste of iron takes place in the refining, amounting on the average to about 10 per cent. on the pig iron. In puddling refined metal, the waste is not more than from 4 to 7 per cent. In the mill-furnace the waste is much less, varying, according to the number of reheatings, and the size to which the iron is rolled, from 3·5 to 10 per cent. The consumption of iron in any stage of the manufacture, requisite to produce a ton of iron in a subsequent stage, is technically called the "yield," by a somewhat singular inversion of the meaning of the term.

The consumption of fuel in the various stages of the conversion of pig iron into malleable iron, varies according to the skill of the workmen, as well as the kind of fuel and iron used. In refining, from 6½ to 8 cwt. of coke per ton of metal made, is used when the pig iron has to be melted, and from 4 to 5 cwt. when the melted metal is run in from the blast furnace direct.

In "pig-boiling," the consumption of coal varies from 18 to 22 cwt. per ton of bar iron made, according as the coal is more or less bituminous and capable of burning with flame.

In puddling refined metal, the consumption is about 10 to 14 cwt. of bituminous coal, and from 17 to 18 cwt. of anthracitic coal per ton of iron made.

In heating the piles, the consumption of fuel is from 7 cwt. to 13 cwt. per ton of merchant bars, according as they are larger or smaller.

In connection with the consumption of fuel in the conversion of pig iron into malleable iron, it will be interesting to consider what amount of the heat, capable of being generated by the coal consumed, is really effective; how much of it is really used in heating the iron.

The temperature to which the iron requires to be heated in the puddling furnace may be taken as expressed by 1650° C.; and, assuming that the specific heat of cast iron increases above 350° C. in the same ratio that it does up to that temperature, it would, in that case, be about 0·26 at 1650° C.; accordingly, the quantity of heat requisite to raise iron from 15° C. to that temperature would be:

heat units.
$$424{\cdot}84 = 1650 - 15 \times 0{\cdot}26.$$

A further quantity of heat would be consumed in melting the iron, and though the latent heat of iron has not been determined, it may be assumed as equal to 30 heat units. Thus the total heat requisite to heat cast iron up to 1650° C. and to melt it would be:

heat units.
$$454{\cdot}84 = 424{\cdot}84 + 30.$$

and the quantity of heat requisite for one ton of iron would be:

heat units.
$$1{,}018{,}841{\cdot}6 = 2240 \times 454{\cdot}84.$$

Taking the average calorific power of coal, expressed in heat units, to be 7,778, it appears from the foregoing calculation, that the quantity of heat actually communicated to the iron amounts to less than that capable of being generated by 131 pounds of coal. Thus:

Coal, lbs.		Calorific power, heat units.		Quantity of heat generated, heat units.	Quantity of heat required to heat 1 ton of iron from 15° to 1650°C. and to melt it, heat units.
131	×	7,778	=	1,018,918	1,018,841·6.

Then, taking the quantity of coal consumed in puddling as being equal in weight to the pig iron worked, it appears that only 133 pounds out of every ton of coal burnt in the puddling furnace is really effective in heating the iron, or not more than one-sixteenth part. But though the quantity of heat actually communicated to the iron bears only this small proportion to the whole quantity generated by the combustion of the fuel used, it must be remembered that, under existing circumstances, this large consumption of fuel is unavoidable, since it is indispensable that, during the whole of the operation, the temperature should be maintained sufficiently high to keep the iron melted. For this purpose the rate of combustion must be high, and the intensely heated products of combustion must pass rapidly through the working chamber of the furnace. It has been estimated that in the ordinary puddling furnace, when the consumption of coal is at the rate of 240 pounds per hour, the volume of heated gas passing through the working chamber amounts to upwards of 72 cubic feet per second, or sufficient to fill the working chamber twice in a second, and that this is necessary in order to counteract the influence of conduction and radiation in reducing the temperature. (See Prideaux, *Elementary treatise on Fuel, particularly with reference to Reverberatory Furnaces.*)

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nsequence of the extremely high temperature required to be maintained in d mill furnaces, that only so small a fraction of the heat generated by com- he fuel consumed, is really effective in heating the iron (Fuel, ii. 729), it is only the heat corresponding to the difference existing at any moment temperature of the iron, and the higher temperature of the atmosphere in chamber of the furnace, that is available for maintaining or raising the tem- the iron. So long therefore as the temperature of iron in a puddling furnace e 1650° C., the gas passing into the chimney must be at a temperature not at, and the whole of the heat corresponding to the quantity of gas discharged erature into the chimney, will be without any other useful effect. A variety ents have been contrived for turning this waste heat to account in raising riving the machinery of iron works; and by far the most simple and con- consists in doing away with the separate chimney to each furnace, and the heated gas escaping from the working chamber of several puddling o a spacious underground culvert, extending some distance away from the d communicating with flues passing through and round a large Cornish which the gas passes, and, after communicating its heat to the water, is ged into a lofty chimney capable of producing a draught sufficient for all connected with it.

umber of attempts have been made to introduce other improvements in of producing malleable iron by puddling; such, for instance, as the use of hot air, or of steam, or a mixed blast of air and steam, rotary puddling ., but excepting the admixture with the pig iron of materials containing oxides, and the use of iron hearth-bottoms in the puddling furnace, none of ts appear to have either any such scientific basis as to appear promising, een attended with sufficient success to demand consideration.

is different as regards the application of gaseous fuel in the refinery, rnace, and mill furnace. The gas used for this purpose is either the com- evolved from the throat of the blast furnaces in which pig iron is made, or pecially from small coal and other inferior kinds of fuel, by burning them in ner that the carbonic acid generated by the combustion of one portion, is s through a mass of incandescent fuel, so as to be converted into carbonic , together with the hydrocarbon vapours driven off from the fuel, passes ace to be heated, and is there burnt, much in the same manner as coal gas Bunsen's burner (See Bischof: *Die indirecte aber höchste Nutzung der rohen ialen*, 1848; also Scheerer, *Metallurgie*, i. 339). This method of using g been practised in Germany, and is now being introduced at some of the n this country, where it is to be hoped it will eventually not only admit of sed in iron working, without those disadvantages arising from the presence nd other impurities, when it is in contact with the metal; but that it may ome an important means of economising fuel, and especially of turning to t the vast quantities of small coal that have hitherto been almost entirely r descriptions of gas generators, and gas refining, puddling, &c., see the e quoted, and Percy, *Metallurgy*, ii. 596, 674, 716; *Ure's Dictionary of factures, &c.* ii. 573.

pheric process.—Under this designation, an entirely new method of alleable iron from pig iron, has been proposed within the last few years as for the operation of puddling. It consists in submitting melted pig iron of a current of air forced through it until it is sufficiently decarburised. nerated during this process, by the combustion of the carbon and silicon, and of the iron, is sufficient to heat the metal above the melting point of on, so that, when the operation is ended, the decarburised iron is obtained condition, and may be run into ingots, which are afterwards to be forged into ssemer, specifications, 1855, Nos. 2321, 2768; 1856, Nos. 356, 630.)

principle of this method is to effect the conversion of pig iron into on, wholly by the direct influence of atmospheric oxygen, and independently ction between the pig iron and the ferruginous or manganese oxides, or ntaining them, which takes place in the operation of puddling or boiling, according to all experience, and to such scientific data as there are for opinion, is so important a condition of the separation of sulphur and phos- pig iron. The result of the trial of this new method of producing on affords a still further confirmation of the important influence of the erred to as taking place in puddling. By the new method pig iron may be burised, and the silicon it contains may be entirely eliminated with ease; se is very different as regards the sulphur and phosphorus: for these which are so detrimental to malleable iron, far from being separated from subjected to this new mode of treatment, are either wholly unacted upon,

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or so little affected, that, relatively, they are augmented, the amount of phosphor the decarburised iron obtained by this method, being greater than it was in th iron operated upon, while the amount of sulphur is but little reduced, as will be see the following analyses:

	Pig iron, per cent.	Bessemer iron, per cen
Analyst .	Tookey.	
Carbon	3·309	0·218
Silicon	0·595	
Sulphur	0·485	0·402
Phosphorus	1·012	1·102

At the present time no means of obviating this defect are known; consequently application of this method is confined to the working of such kinds of pig iron a practically free from sulphur and phosphorus; and hence, as regards the greater of the malleable iron manufactured in this country, there is no possibility o adoption of this method, although it admits of the decarburation of pig iron with greater ease, and much more rapidly than the operation of puddling. In Swede the contrary, where the pig iron produced is far less contaminated with sulphur phosphorus than most of that made in this country, the new method is being wo with great advantage. In England, it is also being applied in working some o better and more costly kinds of pig iron, but chiefly for the purpose of produc kind of steel which bears a higher price than ordinary malleable iron. For this re the further consideration of this method will be included in the article on STEEL.

5. **Iron smelting.**—In the extraction of iron from such of its ores as are suitab metallurgic purposes, and as it is now chiefly practised in iron-producing countries metal is always obtained in the carburetted state, commonly known as cast iron iron, or crude iron. The processes comprised in the smelting of iron are:—

1. The separation of water, carbonic acid, sulphur, and other volatilisable substa from the ore by the action of heat.

2. The reduction of the iron from the state of oxide, as it exists in the ore, t metallic state, by the action of carbonic oxide.

3. The separation of the earthy substances, commonly present in iron ores, from reduced metal, in consequence of the formation, at a high temperature, of fu compounds of those substances; and

4. The carburation and melting of the reduced metal.

In smelting the richer kinds of iron ore, *calcination* or *roasting* (*Röst grillage*) is not always requisite for the removal of volatilisable substances; but the majority of the iron ores used in that operation, it is very desirable that should undergo this preparatory treatment, as will be seen by reference to the ana of iron ores; and in all cases calcination is advantageous, inasmuch as it has the e of rendering the ore more porous, and consequently more susceptible of being duced.

The calcination of iron ores is effected by heating them to dull redness in co with air, either in heaps, with layers of coal at the bottom and alternating with l of the ore; or in kilns built of brick or masonry, from which the roasted ore ca drawn out at the bottom. The careful regulation of the heat applied is the important requisite in the calcination of iron ores, and it should be only just suffi to expel the volatilisable substances, without effecting, in the case of carbonaceous the reduction of iron to the metallic state, or, in the case of siliceous ores, the forma of ferrous silicate and fusion of any portion of the ore, so as to render it compact.

The changes effected by calcination consist chiefly in the separation of water, bonic acid, and bituminous substance when the ores are carbonaceous. In this case t may be a partial deoxidation of the ore, attended with formation of ferrous or magn oxide; but more generally the calcination of iron ores has the effect of producing f oxide to a greater or less extent, if the iron is not already in that state.

The sulphur in iron ores, generally present in the state of pyrites, is also to a g extent separated from them by calcination, in consequence of the decomposition of pyrites; one half of the sulphur being volatilised, while the residual iron sulphi converted by oxidation into sulphate, which may be decomposed if the heat is s ciently great The entire separation of sulphur from iron ores in this way is sel practicable.

An alteration of some kinds of iron ore similar to that resulting from calcina especially as regards separation of sulphur, is effected by exposing them for a tim the atmosphere. In this process of *weathering* (*Verwitterung*), pyritic minerals

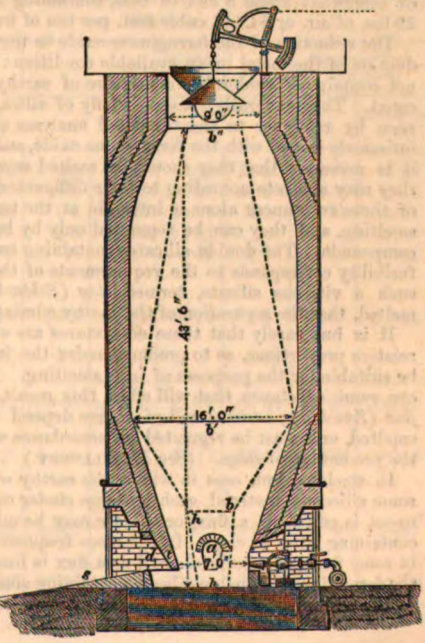
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s, which may be washed out to some extent by
he peroxidation of the ore that takes place in
c air, has the effect of disintegrating the ore and

olatilisable constituents of iron ores, instead of
ion, takes place in the blast furnace, and is then
g, the heat requisite for the purpose being derived
rough the charge. It is probable that in some
economy of fuel, and that if the height of the
upper part would serve as a substitute for the
gas discharged from the throat might be reduced
eat generated in the furnace thus rendered effec-
to the adoption of this plan, consisting in the
l and ore, and their liability to become crushed
aterials in the shaft. In the Cleveland district,
and the fuel used is a very hard coke, furnaces
et high, and the temperature of the gas has been
8° C. instead of 381° C. (I. L. Bell, *Industrial*
s, p. 107). But this saving is only partial, and
last furnace is attended with disadvantages as
vaste heat of the gas discharged from blast fur-
e seen whether that plan can be adopted so as to
economy in fuel.

cted in a furnace consisting essentially of two
ular chamber, built of stone and lined with fire-
uel and the melting of the reduced ore and flux
ider cylindrical chamber, built above the hearth,
rge of ore, flux, and fuel continuously supplied at
he heated gas resulting from combustion, before
and dimensions of this furnace, which is termed
eau) vary considerably (see Truran, *op. cit.* pp.
i. 350, 475, and 559). One of the most approved
this case, the distinction between the hearth,
ed than it is in some furnaces where the hearth is
le, with its sides vertical and terminating in a
ne lower part of the shaft, *b b'*, termed the *boshes*

Fig. 586.



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there is a channel, called the *tapping hole* (*Stichloch; trou de coulée*) co with the hearth, to admit of the melted metal collected at the bottom o being run out at intervals. This channel is stopped up with clay or the metal and slag are accumulating in the hearth. That side of th wards which the hearth is prolonged, is called the *front* (*Arbeitsseite térieure*), while the opposite side is called the *back* (*Rückseite; partie* At this side there is an arched opening, *a*, called the *tuyere hole* there is generally a similar opening at each of the other sides. Oppo these openings an arch is turned in the outer brickwork of the furnace access to the tuyere holes. The upper extremity of the shaft is calle (*Gicht; gueulard*), and is generally surmounted by a low wall or chimne *tunnel head*, with openings at the side for introducing the materials into t

Air is supplied to the furnace through a series of pipes connected wi engine, each pipe terminating with a conical tube called a *tuyere* (*Du* surrounded with a hollow conical sheath, through which passes a stream prevent the melting of the tuyeres, extending through each of the tuyere h the interior surface of the hearth.

In the working of a blast furnace, the shaft is kept nearly filled wi materials used; these are introduced at intervals into the upper end, a sink down as the smelting progresses. Meanwhile a continuous supply of into the lower end of the furnace through the tuyeres, under a pressure 2 lbs. per square inch in charcoal furnaces; and from 2 to 5 lbs. per sq furnaces worked with coal or coke, and in quantity proportionate to th furnace and its rate of working, so as to maintain a rapid combustion o that part of the furnace immediately above the level of the tuyeres. (S *op. cit.*, p. 115.)

The reduction of the ferruginous oxides in the ore is effected by the rea place at a high temperature between these oxides and carbonic oxide, the combination of carbonic acid, resulting from combustion of the fuel, w quantity of carbon equal to that it contains; and, since ferric oxide contains of oxygen, the carbon and air requisite in these reactions for the reductio tity of ferric oxide containing 1 pt. of iron will amount to:

Iron.		Ferric oxide.		Parts by weight of carbon requisite in the state of carbonic oxide.		Parts by weight of oxygen requisite to form carbonic acid with half the carbon.	
1	=	1·429	=	0·3214	=	0·4285	=

or somewhat about 8 cwt. of coal, containing 80 per cent carbon, and 1 29 lbs. of air, or 54,443 cubic feet, per ton of iron made.

The reduction of the ferruginous oxide in the ore is not alone sufficient duction of the metal in an available condition: for it is but seldom that not contain a considerable admixture of earthy substances which require rated. They generally consist chiefly of silica, clay, or carbonate of lim seen by reference to the tabulated analyses of iron ores. These subst intimately mixed with the ferruginous oxide, and consequently with the re it is necessary that they should be melted as well as the metal itself, in they may separate according to their different densities in the liquid state of these substances alone is infusible at the temperature commonly produ smelting, and they can be separated only by being converted into sufficie compounds. The double silicates containing two or more bases, are subst fusibility corresponds to the requirements of this case, and it is by the such a vitreous silicate, termed *slag* (*Schlacke; laitier*), capable of be melted, that the separation of the earthy admixtures in iron ores is effecte

It is but rarely that these admixtures are of such a nature, and pres relative proportions, as to produce, under the influence of heat, a silicate be suitable for the purposes of iron smelting. Hence it is necessary to m ore some substance that will effect this result. The nature and propor *flux* (*Zuschlag; castine*) will of course depend upon the composition of t smelted, and must be regulated in accordance with the general principles the production of slags. (See METALLURGY.)

In smelting iron ores in which the earthy admixture is chiefly calcare some siliceous material, such as forge cinder or the roasted slag from pu naces, is added as a flux, or the ore may be mixed, in suitable proportion containing silica or clay. In the more frequent case of ores containing cl in some form, the material used as a flux is limestone or quicklime, in ord the formation of a double silicate containing alumina and lime as its basic c

The fusibility of the double lime and alumina silicates varies according

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existing between the silica and the bases, as well as that between the two The most fusible of them are those in which the oxygen of both bases amounts thirds of that in the silica, and the oxygen of the lime equals that in the

melting iron ores with charcoal, the temperature of the furnace is generally han when they are smelted with coke or coal, and on that account the slag to be more fusible than in the latter case. In smelting iron ores with coke especially when hot blast is used, the temperature is so much higher than in s worked with charcoal—not only where fusion takes place, but also at the art of the furnace—that the slag requires to be rendered less fusible by increas- proportion of lime to such an extent, in relation to the silica and alumina in that fusion may not take place before the reduction of the ore has been com- effected, and that the fragments of the charge may not become agglutinated, ain loose and porous while passing through that portion of the shaft where on takes place, and consequently more capable of being permeated by the g gas.

e smelting of siliceous ores there is a further necessity for the addition of lime, ore important than that connected with the production of a suitably fusible This arises from the circumstance that the double silicate, containing alumina rous oxide as its basic constituents, is very fusible, and from the consequent y to the formation of this compound, the result of which would be that a con- e amount of the iron would escape reduction to the metallic state, and pass off lag, thus giving rise to considerable loss of iron, besides other serious incon- es. This combination of ferrous oxide with the aluminous silicate in the ore t take place in the presence of a sufficient amount of lime, and in order to it as much as possible, the quantity of lime added to the ore is generally to form a slag in which the oxygen of the bases is equal to that in the silica.

Analyses of Slags from Blast Furnaces.

Locality	Edsken, Sweden.	Peitz.	Königshütte.		Rübeland, Harts.	Hammhütte.	Siegen.	Olsberg, Westphalia.
Ore used	—	Bog iron ore.						Red and brown iron ore.
Fuel used	Charcoal.							
Kind of iron made					Mottled pig.			Specular iron. Hot blast.
Analyst	Ullgren.	Karsten.						Rammelsberg.
s oxide	0·95	1·45	0·2	. .	2·44	21·5	0·06	1·27
nous oxide	1·86	1·40	11·6	4·30	2·20	29·2	33·96	3·16
na	4·30	6·25	6·7	12·60	13·04	2·1	6·63	5·71
	38·64	19·71	26·9	42·85	25·67	. .	. .	27·60
sia	7·40	0·70	. .	. .	0·57	8·6	10·22	7·01
	0·30							
	1·38							
	46·37	70·12	54·1	39·60	53·79	37·8	48·39	55·25
noric acid	traces							
r	0·03	0·37	0·5	0·65	. .	0·80		
	100·00	100·00	100·00	100·00	97·71	100·00	99·29	100·00
of oxygen in s to oxygen in a	0·697	0·257	0·480	0·917	0·512	0·547	0·572	0·385
of oxygen in s to oxygen in nina	7·301	2·180	3·293	2·00	1·400	15·000	3·730	3·037
tage of iron	0·740	1·130	0·160	. .	1·900	16·720	. .	0·990

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Analyses of Slags from Blast Furnaces—continued.

Locality	Mägdesprung, Hartz.				Eisenerz, Styria.	Sweden. Gesberg.		Ed bra
Ore used	Spathic, red, and brown iron ore.				Magnetic iron ore.			
Fuel used	Charcoal.							
Kind of iron made	Hot blast.							
Analyst	Rammelsberg.			Bromeis	Wehrle.	Oengren	Sjögeen.	Folli
Ferrous oxide	4·03	0·44	3·25	5·83	1·4	1·68	3·29	1·
Manganous oxide	25·04	24·85	24·53	22·18	28·6	2·81	2·63	4·
Alumina	5·88	4·96	11·27	5·12	2·6	6·62	5·38	5·
Lime	20·56	26·66	21·55	20·00	10·4	19·35	19·81	18·
Magnesia	2·41	1·10	0·82	2·18	1·3	10·46	7·12	13·
Silica	39·99	41·49	38·58	43·58	54·6	58·60	61·06	58·
Sulphur	. .	. .	. .	CaS 1·11	1·1			
	97·91	99·50	100·00	100·00	100·0	99·52	99·29	99·
Ratio of oxygen in bases to oxygen in silica	0·752	. .	. .	. .	0·458	. .	. .	0·45
Ratio of oxygen in bases to oxygen in alumina	0·481	. .	. .	. .	8·951	. .	. .	4·82
Percentage of iron	3·130	0·340	2·420	4·560	1·090	1·310	2·460	0·78

Analyses of Slags from Blast Furnaces—continued.

Works	Dowlais.			Dudley.	Russell's Hall.	Providence, Charleroi, Belgium.	Russell's Hall.	Cwm, Celyn
Ore used	Clay iron ores of the coal measures.							
Fuel used	coke.				coke.			
Kind of iron made	white forge pig.	grey pig.	hot blast.					white pi
Analyst	Riley.			Percy.	Forbes.	Percy.	Dick.	Noad.
Ferrous oxide	3·08	6·91	0·76	1·27	0·93	4·94	1·00	19·80
Manganous oxide	1·02	1·67	1·62	0·40	2·79	2·26	2·20	1·53
Alumina	11·55	15·51	15·13	14·11	13·01	13·05	12·91	20·20
Lime	32·09	23·81	32·82	35·70	31·43	32·53	29·92	10·19
Magnesia	3·78	4·38	7·44	7·61	7·27	1·06	4·79	2·90
Potash	1·53	1·98	1·92	1·85	2·60	2·69	0·87	1·10
Silica	45·23	44·88	38·48	38·05	37·91	42·06	47·08	42·96
Phosphoric acid	. .	0·43	0·15	. .	. .	0·19	0·05	
Calcium	1·04	0·59	1·23	0·82	3·65	1·03	1·78	1·32
Sulphur	0·83	0·47	0·99					
	100·15	100·63	100·54	99·81	99·56	99·81	100·60	100·00
Ratio of oxygen in bases to oxygen in silica	0·716	0·691	0·99	1·01	0·953	0·81	0·691	0·822
Ratio of oxygen in bases to oxygen in alumina	2·18	1·45	1·85	2·09	2·15	1·88	1·87	0·929
Percentage of iron	2·39	5·37	0·60	0·99	0·62	3·84	0·80	15·40

The characters that are generally considered to be indicative of the formation of suitable slag, consist in its being sufficiently liquid to separate perfectly from t metal, though as it flows from the furnace it is generally somewhat viscous. Wh solidified, it should not be vesicular, but compact and homogenous, without bei

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very vitreous or stony. The colour of slag from blast furnaces varies very but does not afford much indication of its character. When charcoal is used as e slag is lighter coloured than that from furnaces in which coal or coke is used. published analyses of blast furnace slags are very numerous; but comparatively e any real value, from the absence, in most instances, of any statements as to ditions under which the slags were produced. For the elucidation of the pro- hat take place in the smelting of iron ores, so far as the formation of slag is ed, it is essential that the analyses of slags should not only be numerous, but ey should also be accompanied by descriptions of the kind of iron made, and king condition of the furnace, as well as of the kind of ore, fluxes, and fuel em- The analyses on pp. 359 and 360 will serve to illustrate the general character lag produced in iron smelting.

me kinds of iron ore, the relation existing between the silica and alumina is ferent from that generally obtaining in the clay iron ores of the coal measures, as seen from the following table and by reference to the analyses of ores.

	Low Moor.	Brierly.	Stanton.	Butterley.	Parkgate.	Cleveland.
ina . .	23	24	20	26	24	25
. .	9	9	13	11	13	27
esia . .	8	7	17	9	19	14
. .	60	60	50	54	44	34
	100	100	100	100	100	100

nsequence of this difference, and the greater proportion of alumina in the ores Cleveland district, the slags produced in smelting them are much more stony s vitreous than those produced in smelting other ores. An increased addition would not remove this difference, which is due to the deficiency of silica in ion to the alumina present, and is probably accompanied by a less degree of ty of the slags. This circumstance will perhaps serve to account for the appa- cessity of a very high temperature in the smelting of these ores, and for the of the attempts that have been made to smelt them with cold blast. (I. L. Bell, p. 96.)

Analyses of Slags from Cleveland Ores.

Name of works	Clarence, Middlesbro'.				
Ore used . .	Clay iron ore smelted with coke and hot blast.				Flue dust from blast furnace gas.
Analyst . .	Crowder.	Clarence Laboratory.			
c oxide	. .	. .	. .	. .	8·20
us oxide	0·72	3·64	0·61	0·32	
ganous oxide . . .	0·35	1·02	trace	0·80	
oxide	. .	. .	. .	. .	4·60
ina	24·69	20·72	22·28	21·70	16·00
. . . . .	40·00	36·88	40·45	38·72	12·15
esia	3·55	4·25	7·21	6·10	0·57
h	0·46	0·50	. .	. .	0·40
. . . . .	0·99	. .	. .	. .	6·85
. . . . .	27·65	30·40	27·80	29·92	34·82
phorus	0·26	. .	. .	0·07	
ur	1·95	1·34	2·00	1·61	8·80
rine	. .	. .	. .	. .	1·56
r	. .	. .	. .	. .	5·60
	100·62	98·75	100·35	99·24	99·55
o of oxygen in bases to oxy- n in silica	1·675	2·042	1·687	1·600	
o of oxygen in bases to oxy- n in alumina . . .	1·127	2·394	1·392	1·346	
entage of Iron . . .	0·560	2·830	0·470	0·250	

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The preceding analyses of slags from furnaces in which the Cleveland ores are worked, will illustrate the difference between them and the slags produced in other districts.

The precise mode in which the carburation of iron takes place in the blast furnace is not known. From the fact that iron becomes carburated when heated in contact with hydrocarbon gases, or even with carbonic oxide, and since these conditions obtain in the blast furnace, it is highly probable that carburation may take place before the reduced iron reaches that part where there is a temperature high enough for fusion.

The state in which the carbon exists in the iron obtained from the blast furnace appears to depend very materially upon the temperature at which fusion takes place. The lower the temperature, the greater is the proportion of the carbon combined with the iron, and any circumstance which tends to induce fusion at a low temperature is almost invariably attended with the production of white iron. This is the case when charcoal is used as fuel, when the ore is readily fusible, and also when it is highly refractory and has not a suitable admixture of flux to determine fusion. When a furnace is worked with a large amount of ore in proportion to the fuel, or, as it is termed, with a "heavy burden," and when sulphur is present to any large extent, there is from the same reason a tendency to the production of white iron.

The production of grey iron containing carbon in the graphitic condition appears to require a temperature far beyond that of mere fusion, and it is probable, on that account, the introduction of carbon in this form may be due to action more of a physical than chemical nature, and consist in solution of the carbon by the melted metal rather than actual combination. When sulphur is present in any of the materials used in smelting iron, it is necessary to employ a very high temperature in order to obtain grey iron, because the melting point of iron is considerably lower when it contains sulphur.

Besides the reduction of the ferruginous oxide in the ore and the separation of its earthy constituents by the formation of a suitable silicate, it is necessary to maintain a very high temperature at the lower part of the furnace for the fusion of these products. This is effected by the rapid combustion of fuel under the influence of a blast of air forced in through the tuyeres.

The kind of fuel employed in smelting iron ores has a great influence both on the quality of the iron produced and on the mode of working. With bulky porous fuel, such as charcoal, combustion takes place more readily than with the more compact and denser kinds of mineral fuel, and from the greater liability of charcoal to crumble under pressure, the furnaces in which it is used are generally much smaller than those worked with coal or coke. But the main difference between these two kinds of fuel, as regards the smelting of iron, consists in the relative freedom of charcoal from earthy substances, and its entire freedom from sulphur and phosphorus, which are so prejudicial to the quality of iron. Hence the greater purity of the iron smelted with charcoal, provided the ore used be free from deleterious admixtures.

The consumption of fuel requisite in smelting iron for the production of a sufficiently high temperature of fusion, far exceeds the amount requisite for the reduction and carburation of the metal, which, as already pointed out, is less than half the weight of the iron produced, whereas that consumed for melting may amount to from one to two or three tons per ton of pig iron made.

The consumption of fuel in iron smelting is one of the most important points with regard to the economical production of the metal, and it is exceedingly desirable to reduce it to the lowest possible limit. The amount of fuel consumed per ton of pig iron made varies considerably, not only according to the kind of fuel, its calorific power, combustibility, texture, etc., but also according to numerous other circumstances. Among these the shape of the furnace has an influence, in so far as it admits of the easy and uniform descent of the charge in the shaft, and less fuel is consumed in making white iron than in making grey or foundry iron; but probably the most important difference in the consumption of fuel is that resulting from the use of air at the ordinary atmospheric temperature, or air previously heated to a temperature considerably higher.

In charcoal furnaces, the consumption per ton of pig iron made, is from half a ton to two tons and upwards, according as hot or cold blast is used. In smelting with coal or coke, the consumption is from two to three tons and upwards with cold blast, and from 23 cwt. to two tons with hot blast.

The fuel is introduced into the furnace at intervals alternately with the mixture of ore and flux, and in uniform proportions, termed the *charge* (*Beschickung; lit de fusion*), and the relative proportion of fuel or of ore is termed in either case the "yield;" sometimes also in the case of the ore it is termed the "burden."

The total weight of the charge per ton of pig iron made, will vary, according to the kind of ore, flux, and fuel used, from four to five or seven tons and upwards, when the materials are used in the raw state; but by far the greater quantity of the material supplied to a blast furnace in smelting iron, consists of the air by which combustion is

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orted: for taking carbonic oxide to be the ultimate though not the immediate uct of the combustion, the quantity of air required would amount to at least five s the weight of the fuel burnt, taking the combustible portion of the fuel to be l to 85 per cent. of carbon, and allowing for the carbon consumed in carburating ron. Consequently the total quantity of air supplied to blast furnaces will be as ws, according to the consumption of fuel given above:

	tons. cwt.	tons.	tons.	
uel consumed . . .	23	2	3	per ton of iron made.
uantity of air . . .	5 15	10	15	
ubic feet at 60°F. . .	168,038	292,240	438,360	

ne greater part of this air is consumed in burning that portion of the fuel isively concerned in the production of a temperature high enough for effecting n; and that part which is consumed in the combustion of the fuel requisite for eduction of the ore, does not amount to quite twice the weight of the iron made.

ne temperature of the gaseous products of combustion discharged from blast aces differs according to the kind of materials used and their condition, the height ne shaft, and the mode of working. In the case of charcoal furnaces, the gas has rally a temperature of from 300° to 400° C., while that from furnaces worked with or coal, is from 550° to 1000° C., according to circumstances. The whole of the corresponding to the temperature of the gas discharged is waste heat, and ough it has served, at an earlier stage of the process, to produce the high temperature ssary for fusion of the metal and slag, it is still available for any purpose to which n be applied.

ne great extent to which the heat generated in the smelting of iron ores is thus pated, without producing the full useful effect of which it is capable, may be ed of from the fact that the weight of the gas discharged from a blast furnace is than equal to the entire quantity of both air and fuel consumed, or from 17 tons per ton of pig iron made.

ut besides the waste of heat due to the high temperature of the gas discharged, there further and more considerable loss of heat, due to the fact that it contains a large unt of carbonic oxide, together with some hydrocarbons and hydrogen, and is in all nary cases sufficiently combustible at the temperature at which it is discharged, to fire on coming in contact with atmospheric air at the top of the furnace. This e is proportionate to the extent to which carbonic oxide is produced. Taking the age consumption of fuel in iron smelting to be represented by a quantity of carbon l to twice the weight of the pig iron produced, if that portion only which is isite for the reduction of ferric oxide be ultimately discharged from the furnace in state of carbonic acid, the quantity of fuel fully utilised in producing the entire ing effect of which it is capable, will be only about one-sixth part of the whole.

	Quantity of heat generated by perfect combustion of carbon. parts by weight					
	2	:	0·3214			
Heat units .	16160	:	2596	=	6·225	: 1

hen, since the calorific power of carbon burnt to carbonic oxide is only about one- d of its calorific power when burnt to carbonic acid, or as

2473 : 8080 = 1 : 3·223,

heating effect produced by the remaining five-sixths of the fuel consumed, so as regards its ultimate condition when discharged from the furnace, will be less one-third the effect it is capable of producing:

antity of heat able of being erated by com- on of 1·6786 car- o carbonic acid. heat units.		Quantity of heat generated by com- bustion of 1·6786 car- bon to carbonic oxide. heat units.					Difference.
13564	—	4151·1778	=	1·6786	×	2473	= 9413

difference representing the heating effect capable of being produced by the carbonic le, and amounting to no less than 58·25 per cent. of the whole heating effect able of being produced by the fuel consumed.

o far, therefore, as regards the condition in which the products of combustion are harged from a blast furnace, the only portion of the fuel consumed so as not to be her available as a source of heat, is that equivalent to the reduction of the iron in ore, and, supposing the metal to be contained in the ore in the state of ferric le, it would be only about one-third the weight of the iron made, or 16 per cent.

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of the fuel consumed. The greater part of the heat corresponding to the r
84 per cent. of fuel consumed, leaves the furnace in some form or other in th
sensible heat, or as heat capable of being generated by combustion, and is still
for heating purposes.

But, notwithstanding this large difference between the amount of fuel full
and that which still remains available as a source of heat, after its combusti
blast furnace, it must not be supposed that the large amount of fuel consume
smelting, as compared with the amount which is fully utilised, does not, in
furnace, exercise its full heating power. For though only a small portion of t
heat generated is rendered latent by the fusion of the metal, &c., the whol
required for producing the temperature at which those changes take place;
which passes off in the gas does not indicate a useless consumption of fuel, and
be regarded as waste heat, in so far as it is allowed to escape without being
such further advantage as it is still capable of.

In the immediate neighbourhood of the tuyeres, the fuel is burnt, under
ence of the blast, to carbonic acid, generating the full amount of heat corre
to its calorific power, and producing there the greatest increase of tempera
capable of producing when burnt with atmospheric air. (See Fuel, ii. 726.)

It is at this part of the furnace that, while the fuel is being consumed, th
metal and the earthy substances mixed with it are rapidly melted, and, fall
into the hearth, make room for a fresh quantity of the materials in the shaft of th
to sink down and undergo the same change, while the gaseous products as
communicate their heat to the materials in the higher part of the shaft.

When the iron ore smelted contains carbonic acid or water, and has
previously calcined, those substances will be separated during the descent of t
in the shaft, and will mix with the products of combustion. This will also b
with the carbonic acid of the limestone used as a flux, and if coal be used a
volatilisable portion will likewise be expelled, and mix with the ascending gas.

In proportion as the extent of this admixture is greater, the gas will hav
heating power when burnt, and therefore it is desirable to reduce the amou
bonic acid and water-vapour in the blast furnace gas, by previous calcinati
ore and limestone, whenever the gas is to be used as fuel.

As a consequence of the different physical conditions of the products resul
the changes that take place in smelting iron ores, those products are continu
charged from the blast furnace in a manner exactly the reverse of that in
raw materials are supplied to it; the melted iron and slag flowing out at th
while gas escapes from the top or throat of the furnace.

In considering more minutely the conditions under which these products ar
and the chemical nature of the changes from which they result, it will be c
to follow the course of the air supplied to the furnace as it passes from the
the top.

The direct and perfect combustion of the fuel is, in all cases, confined with
paratively small portion of the furnace, and in furnaces worked with charcoal, i
only to a short distance above the level of the tuyeres. Beyond that porti
furnace, heat is communicated to the materials in the upper part of the furna
ascending heated gaseous products of combustion, consisting of a mixture of
and carbonic acid, the temperature of the gas being proportionally reduce
as it passes up to the mouth of the furnace. But since the materials in th
the furnace immediately above the region of combustion are at a high red
carbonic acid enters into combination with a further quantity of carbon, an
verted perhaps entirely into carbonic oxide, its volume being thereby doubl
reaction being attended with a considerable absorption of heat (see Fuel, ii.
temperature of that part of the furnace where it takes place, though still
must be, on that account, much lower than it is within the region of direct co
near the tuyeres.

The following analyses of gas, taken from different heights in the shaft
furnaces, will serve in some degree to illustrate the nature of the changes resul
the reaction taking place between the solid and gaseous materials contain
furnace, and *figs.* 587 and 588 represent the shape of two of the furnaces fr
the gases were taken.

The formation of carbonic oxide is probably one of the most important f
this process: for there is every reason to consider that the reduction of the
as it descends towards the boshes of the furnace, is effected mainly, if not en
this gas, aided perhaps in some cases, by hydrocarbon vapour or gas produ
the fuel by the action of heat. Previously to this, no alteration of the rel
portion existing by weight or volume, between nitrogen and oxygen in at
air, would be effected either by the combustion of the fuel or by the s

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Analyses of Gas from Blast Furnaces.

No.	Name of Works, &c.	Depth below the mouth.	Percentage composition by measure. Nitrogen.	Carbonic acid.	Carbonic oxide.	Marsh-gas.	Olefiant gas.	Hydrogen.	Cyanogen.	Ratio of oxygen to nitrogen.
		feet								
1	Alfreton, Derbyshire. Fuel: coal. Hot blast = 330° C. Bunsen and Playfair.	5	55·35	7·77	25·97	3·75	0·43	6·73	. .	0·374
2		8	54·77	9·42	20·24	8·23	0·85	6·49	. .	0·375
3		11	52·57	9·41	23·16	4·58	0·95	9·33	. .	0·418
4		14	50·95	9·10	19·32	6·64	1·57	12·42	. .	0·368
5		17	55·49	12·43	18·77	4·31	1·38	·62	. .	0·375
6		20	60·46	10·82	19·48	4·40	. .	4·83	. .	0·340
7		23	58·28	8·19	26·97	1·64	. .	4·92	. .	0·371
8		24	56·75	10·08	25·19	2·33	. .	5·65	. .	0·381
9		34	58·05	. .	37·43	. .	. .	3·18	1·34	0·322
10	Seraing, Belgium. Fuel: coke. Hot blast = 100° C.	1	57·06	11·39	28·61	0·20	. .	2·74	. .	0·450
11			56·64	11·39	28·93	. .	. .	3·04		
12		4	59·64	9·85	28·06	1·48	. .	0·97		
13		9	62·46	1·54	33·88	1·43	. .	0·69		
14		9⅝	61·67	1·08	35·20	0·33	. .	1·72	. .	0·301
15			61·15	1·13	35·35	0·29	. .	2·08		
16		11⅔	61·34	0·10	36·30	0·25	. .	2·01		
17		45	54·63	. .	45·08	0·07	. .	0·25	. .	0·412
18	Eckerhagen, Hesse Cassel. Fuel: charcoal. Bunsen.	3	62·34	8·77	24·20	3·36	. .	1·33	. .	0·334
19		4·5	62·25	11·14	22·24	3·10	. .	1·27		
20		6	66·29	3·32	25·77	4·04	. .	0·58		
21		7·6	62·47	3·44	30·08	2·24	. .	1·77	. .	0·295
22		9	63·89	3·60	29·27	1·07	. .	2·17	. .	0·285
23		12	61·45	7·57	26·99	3·84	. .	0·15		
24		15	64·58	5·97	26·51	1·88	. .	1·06	. .	0·296
25	Vordenstein, Nassau. Fuel: charcoal. Ore: magnetic iron ore. Scheerer.	9	64·43	22·20	8·04	3·87	. .	1·46		
26		12	62·65	18·21	15·33	1·28	. .	2·53	. .	0·413
27		14	63·20	12·45	18·57	1·27	. .	4·51		
28		17	64·28	4·27	29·17	1·23	. .	1·05	. .	0·293
29		19	66·12	8·50	20·28	1·18	. .	3·29		
30		22	64·97	5·69	26·38	. .	. .	2·96	. .	0·290
31	Clerval, France. Fuel: charcoal. Hot blast = 175°–190° C.	throat	57·79	12·88	23·51	. .	. .	5·82		
32		3	57·80	13·96	22·24	. .	. .	6·00	. .	0·434
33		8	58·15	13·76	22·65	. .	. .	5·44		
34		12	59·14	8·86	28·18	. .	. .	3 82	. .	0·387
35		16	60·54	2·23	33·64	. .	. .	3·59		
36		17½	63·07	. .	35·01	. .	. .	1·92	. .	0·279
37		tuyere	56·08	0·31	41·59	. .	. .	1·42		
38	Audincourt, France. Fuel: charcoal. Cold blast. Ebelmen.	3¼	57·22	12·01	24·65	0·93	. .	5·19	. .	0·424
39			58·56	11·95	23·85	1·33	. .	4·31		
40		9⅝	60·92	4·14	31·56	0·34	. .	3·04	. .	0·327
41			60·89	4·23	31·34	0·77	. .	2·77		
42		19¾	63·04	0·49	35·05	0·36	. .	1·06	. .	0·206
43			63·06	0·07	35·47	0·31	. .	1·09		
44		27⅝	61·22	. .	37·55	0·10	. .	1·13		
45			58·17	0·93	39·86	0·25	. .	0·79	. .	0·359
46	Audincourt, France. Fuel: charcoal. Hot blast = 250° C.	throat	55·62	12·59	25·24	. .	. .	6·25	. .	0·453
47		11½	54·39	14·46	23·62	. .	. .	7·53		
48		14¾	56·07	9·55	28·82	. .	. .	5 56		
49		18	57·84	7·54	30·03	. .	. .	4·59	. .	0 391
50		21⅝	57·87	3·81	34·28	. .	. .	4·04		
51		26½	61·61	0·21	36·39	. .	. .	1·79	. .	0·298
52	Wibsa, Styria. Fuel: charcoal. Hot blast = 200° C. Tunner.	11	70·50	16·39	13·11	. .	. .	. .	. .	0·325
53		17	71·36	17·80	10·89					
54		23	68·81	9·60	21·59	. .	. .	. .	. .	0·296
55		27	66·66	2·68	30·66	. .	. .	. .	. .	0·270
56		34	66·34	11·60	20·06	. .	. .	. .	. .	0·327

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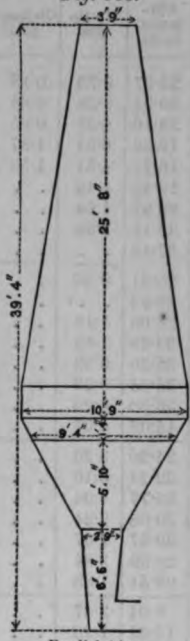
production of carbonic oxide. But by the reduction of the ore resulting from the reaction of carbonic oxide with ferrous or ferric oxides at a high temperature, carbonic acid is again produced, equal in volume to the carbonic oxide undergoing the change, and the effect of this transfer of oxygen from the solid to the gaseous contents of the furnace would be to produce a proportionate alteration of the ratios existing between both the relative weights and volumes of the nitrogen and oxygen. However, the influence exercised by this change on the composition of the gas passing upwards through the furnace will be slight; for, since the consumption of fuel in smelting iron ores so far exceeds the amount that would be chemically sufficient for the mere reduction of the ferric oxide, and since it is probable that the whole of the carbon consumed passes into the state of carbonic oxide at some part of the furnace not far above the level of the tuyeres, it follows that the extent to which carbonic acid is produced by the reaction between ferric oxide and carbonic oxide, must be small compared with the total amount of carbonic oxide produced in the operation; and, in fact, taking the consumption of fuel to be at the rate of 2 pounds carbon to 1 pound of pig iron made, only one-sixth part of the carbonic oxide formed at the lower part of the furnace, would be converted into carbonic acid by the reduction of the iron in the ore from the state of ferric oxide, taking place at the upper part of the furnace.

Fig. 587.



Norwegian charcoal blast furnace.

Fig. 588.



English blast furnace. Alfreton, Derbyshire.

Most probably the reduction of ferric oxide by carbonic oxide takes place progressively, and since the temperature requisite does not exceed that of dull ignition, it may extend over a considerable range in the descending column of materials, in proportion to the temperature prevailing in the upper part of the furnace.

From the relation existing between the calorific power of iron and that of carbonic oxide (see HEAT, p. 105), it is probable that the reduction of ferric oxide by carbonic oxide, generates a certain amount of heat, since the quantity of heat generated by the combustion of iron is less than that generated by the combustion of the carbonic oxide requisite for its reduction from the state of ferric oxide. Thus:

Quantity of heat generated by combustion of 0·75 lb. carbonic oxide, heat units.		Quantity of heat generated by combustion of 1 lb. iron to ferric oxide, heat units.		Difference.
1802·25	—	1582	=	220

Unless, therefore, the thermal effect of the combustion of carbonic oxide by the condensed oxygen in ferric oxide, be different from that of its combustion by gaseous oxygen, this change would be attended with an increase of temperature. But in any case it does not appear that there is any other cause operative in reducing the temperature at the upper part of the blast furnace, save the transfer of heat from the ascending gas to the colder materials supplied from time to time at the top, as the charge descends, and—if hydrated or carbonated ores, or limestone, or fuel containing volatilisable substance, be used—the absorption of heat accompanying the change of water into vapour and of carbonic acid into gas.

Consequently, the maintenance of a high temperature in the upper parts of the blast furnace must have the effect of preparing the materials constituting the charge, for passing rapidly through that stage of the process taking place near the level of the tuyeres, which, as regards the present system of working, consists probably in the mere fusion of the metal and slag, and the combustion of the remaining fuel. Accordingly, a reduction in the quantity of material in the charge would admit of a given temperature being maintained at the upper part of the furnace with a less consumption

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heating the materials in the furnace to such a
sion, is directly proportionate to the quantity
sely proportionate to the temperature of the
qual, such a reduction would also admit of an
duction of the blast furnace, and thus effect a

over and above that requisite for the reduction
shown, to about one-third the weight of iron
effect the fusion of the charge, it follows that
te for this purpose, otherwise than by the com-
nit of a reduction in the amount of fuel supplied
portant, a proportionate reduction in the supply
reduction, a smaller quantity of heat would suffice
ture in a shorter time. The greater the substi-
for the combustion of fuel in the furnace, the
f the amount of fuel requisite in the charge
ary for the reduction of the ore, and the greater
rnace, of the full calorific and reducing power of

llustrate the principle of the economy, both in
f hot blast in iron smelting. The apparently
effect being produced by a less consumption of
isconception in regard to this subject, and has
antage attending the use of hot blast.
el, which almost always contains sulphur, a por-
slag, probably in the state of calcium-sulphide;
ne sulphur, and it is desirable to reduce the
. The means that are considered to be capable
ne proportion of lime in the slag, and the addi-
both of which appear to determine the separa-
e slag.
pears also to be influenced by the proportion of
rature obtained in smelting with hot blast, silica
er extent than is generally the case with cold
amount of lime may render that reduction more
e been made on this subject are not sufficiently
case.
hosphatic ores almost invariably contains the
ore. Experiments made on this subject by
Mag. Dec. 1855) show that this is not due to
supposed; but that it is the natural result of the
Their investigations also lead to the conclusion
e slag is closely connected with the partial re-
a large amount of ferrous oxide in the slag; and
hosphorus from phosphatic ores, such as bog
in this way, whereas by the perfect reduction of
e phosphorus passes into the iron. As yet no
wn, and at the present time the elimination of
important problems connected with the che-

r subjects is, however, attended with very great
ions by which iron is produced do not readily
ally; while on the other hand it is to a great
of the processes involved in those operations
Consequently, though numerous attempts have
chemists, to investigate the chemistry of this
ir labours have been well directed and to some
as been made in knowledge of the subject is far
in the least detracting from the merit of some
he subject, it may be said that, considering the
re, as well as the magnitude of the interests
nade during the last thirty years to its elucida-
highest degree meagre, desultory, and unsatis-

B. H. P.

s of iron are not for the most part of much im-
c, tin, antimony, &c. acquire greater hardness,
ing up a few parts in a thousand of iron. True

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alloys of iron may be prepared by fusing different metals with iron wire, in a blast furnace, a small quantity of ferric oxide being added to decarbonise the iron.

1. An alloy of iron and aluminium, nearly in the proportion Al^2Fe, is obtained by melting 10 pts. aluminium and 5 pts. ferrous chloride with 20 pts. of a mixture of the chlorides of potassium and sodium in equivalent proportions, and treating the resulting crystalline regulus with dilute hydrochloric acid. The alloy then remains in iron-coloured six-sided prisms; it is attacked by hydrochloric acid, and soda-ley extracts from it a small quantity of aluminium (Michel, Ann. Ch. Pharm. cxv. 104). See also ALUMINIUM (i. 155). The peculiar excellence of the Indian steel, known under the name of "wootz," has been ascribed to the presence of aluminium in it; but there is room for doubting whether this is the case (Faraday and Stodart, Quart. Journ. of Science, 1819–20, ix. 320; Karsten, *Eisenhüttenkunde*, i. 484). (See STEEL.)

2. With Antimony (i. 316).

3. With Arsenic. *Arsenical Iron, Arsenosiderite.*—Two compounds of arsenic and iron, Fe^4As^6 and $FeAs^2$, known by these names, occur as natural minerals. They appear to be isomorphous, forming trimetric crystals, in which $\infty P : \infty P = 111° 30'$ (Greg), 122° (G. Rose); cleavage rather distinct in one direction; also massive. Hardness = 5—5·5. Specific gravity, from 6·80 to 8·71. Lustre metallic. Colour between silver-white and steel-grey. Streak greyish black. Fracture uneven. Brittle. Heated in a glass tube, they yield a sublimate of metallic arsenic; on charcoal before the blowpipe, they give off arsenical fumes and leave magnetic globules. Nitric acid dissolves them with separation of arsenious acid.

Arsenical iron always contains sulphur, generally between 1 and 2 per cent.; a specimen from Geier, in the Erzgebirge, contains 6 per cent. If this be reckoned as arsenical pyrites (mispickel), $Fe^2As^2S^2$, the remainder is found to contain, in the lighter varieties (specific gravity 6·24—7·00), from 67·4 to 68·4 per cent. arsenic, and 32·6 to 31·6 iron, agreeing nearly with the formula Fe^4As^6, which requires 66·8 As and 33·2 Fe; and in the heavier varieties (specific gravity 6·80 to 8·71), from 71·35 to 73·49 arsenic, and 27·88 to 26·51 iron, agreeing nearly with the formula $FeAs^2$, which requires 72·84 As and 27·16 Fe. (*Rammelsberg's Mineralchemie*, p. 19.)

Arsenical iron occurs, associated with copper-nickel, at Schladming in Styria; with serpentine at Reichenstein in Silesia, and at Löling, near Hüttenberg, in Carinthia, in a bed of spathic iron ore, associated with bismuth and scorodite; at Geier in the Erzgebirge; in Bedford County, Pennsylvania, and in Randolph County, North Carolina, where a mass was found, weighing nearly two pounds. (Dana, ii. 61.)

Gehlen, by melting 54 pts. iron with 108 pts. arsenic in a closed vessel, obtained an arsenide of iron, having nearly the composition Fe^2As^2; it was white, brittle, and very easily pulverised. Arsenical cast iron (see *ante*, p. 335).

4. With Bismuth.—An alloy prepared by melting together 3 pts. bismuth and 1 pt. iron is still magnetic.

5. With Copper. (See ii. 42.)

6. With Gold.—1 pt. iron forms with $\frac{1}{4}$ pt. gold a silver-white alloy; with 1 pt. gold, a grey alloy.

7. With Lead.—The two metals unite with difficulty when fused together, forming two alloys, arranged one above the other, the lower containing but very little iron, and the upper but a very small quantity of lead (Morveau). By reducing a slag containing lead and iron in a crucible lined with charcoal, Biewend (J. pr. Chem. xxiii. 252) obtained a well-fused alloy, which was hard, almost perfectly brittle, lustrous, and magnetic; it had a light steel-grey colour, a fine-grained laminar fracture, and contained 96·76 per cent. of iron and 3·24 of lead.

8. With Manganese.—Cast iron, alloyed with manganese, becomes white and more brittle; when the proportion of manganese amounts to 22 per cent. the iron ceases to exhibit magnetic properties. (Mushet.)

9. With Mercury.—An amalgam of iron with mercury is described by Joule. (Brit. Ass. Reports, 1850, p. 55.) See MERCURY.

10. With Molybdenum.—Molybdide of iron is bluish-grey, hard, brittle, fine-grained, and magnetic; fusible before the blowpipe when formed of equal parts of the two metals, but not so when formed of 2 pts. molybdenum and 1 pt. iron.

Many samples of the so-called "bears" (*Eisen-sauen*) which are metallic masses found in the hearths of blast furnaces in which copper is smelted, as at Mansfield (ii. 31), likewise consist of iron alloyed chiefly with molybdenum; *a*. Bear from the upper works at Eisleben, obtained in the fusion of bituminous marl-slate in smelting furnaces. α. Fine-grained. β. Coarse-grained (Heine, J. pr. Chem. ix. 176).—*b*. The so-called Magdeburg meteoric iron, containing slag mixed with bronze-yellow copper-cinder; probably the bear from a copper furnace. α is the analysis of a fine-grained sample, β of a coarse-grained sample, by Stromeyer (Pogg Ann. xxviii. 551); γ is the analysis by Wehrle (Zeitschr. Phys. v. W. iii. 168).—*c*. Bear found in the neighbourhood of the

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r Wiggens (Pogg. xxviii. 565). *d.* Bear found erg, J. pr. Chem. xviii. 379.)

	b, α.	*b*, β.	*b*, γ.	*c.*	*d.*
	74·60	76·77	73·11	81·14	50 to 80
	10·19	9·97	5·28	1·08	10 to 30
	0·01	0·02	0·12	0·14	
	3·07	3·25	4·16	2·40	trace
	1·28	1·15	0·84	trace	1 to 6
	4·32	3·40	5·34	7·69	2 to 4
	. .	. .	trace		
	. .	. .	. .	0·29	trace
	0·39	0·35	1·83	1·94	
	0·48	0·38	1·20	0·69	trace
	2·47	1·40	2·70	1·82	
	2·27	1·25	1·38	0·81	2 to 5
	0·92	2·06	2·94	0·62	trace
	100·00	100·00	98·90	98·62	

melt together with facility, forming alloys, some tself. An alloy of 1 pt. iron with 0·03 nickel is sible as iron, and less liable to rust. 1 pt. iron o yellowish colour, specific gravity 7·85, is less sily. 1 pt. iron and $1\frac{1}{2}$ pt. nickel form a grey, nagnetic alloy.

a alloy of iron and nickel. (See p. 336; also

brittle alloy. (Faraday and Stodart, Phil.

its of platinum and iron heated before the oxy- nission of sparks, and form a shining, very hard touched by the file. In equal volumes, the two). Combination does not take place in the heat An alloy of 99 pts. iron and 1 pt. platinum is (Schönbein, Pogg. Ann. xlii. 17.)

latinum are dissolved in nitromuriatic acid, the , the solution precipitated by ammonia, and the of hydrogen at a low red heat, an alloy of iron diately takes fire on exposure to the air. If this in contact with the air, so that no combustion ochloric acid—which dissolves part of the iron residue washed with water, there remains a per cent. platinum to 19·9 iron (which may be ether with a trace of moisture, but no hydrogen. nsiderably below a red heat, and burns with mbustion begins at the hottest part and spreads n the burning of tinder; after the combustion, per cent. in weight. (Boussingault, Ann. Ch.

9 pts. platinum and 2 pts. steel form a perfect sure to the air; specific gravity 15·88. β. The akes a high polish, does not tarnish, exhibits a face, and has a density of 9·862. γ. 1 pt. pla- nasked alloy. δ. 1 platinum to 10 steel: specific pts. steel: the best adapted for cutting instru- teel: of uniform surface, and beautiful fracture; ough, and therefore specially adapted to many el: damasked alloy, very well adapted for razors quantity of platinum dissolves in dilute sulphuric l. This increase of solubility is produced even with a quantity between $\frac{1}{200}$ and $\frac{1}{100}$. With $\frac{1}{40}$ less; steel alloyed with one-half platinum does el; and a compound of 2 pts. steel with 9 pla- lphuric acid. These alloys exhibit the same re-

el with 1 pt. of platinum (or of any other metal ilute sulphuric acid, and the undissolved portion,

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containing platinum, iron, carbon, and hydrogen, is boiled with nitric acid, a black residue is left. This latter substance, when heated to 200°, detonates slightly, producing a faint light, but if gradually heated, decomposes with detonation; it dissolves in nitromuriatic acid, yielding a solution containing a larger portion of platinum, with but little iron. (Faraday and Stodart. Phil. Trans. 1822, p. 257, and Quart. Journ. of Science, p. 329.)

Cast iron and platinum form a dark, malleable, very hard alloy.

14. With Potassium.—An alloy having nearly the composition Fe^4K^2, is obtained by igniting 12 pts. iron filings with 8 pts. pulverised tartar; it has the aspect of bar-iron, is very hard; can be forged and welded, but oxidises very rapidly in air and water. (Gay-Lussac and Thenard, *Recherches Physico-chimiques*, i. 238; Calvert, Phil. Mag. Oct. 1855.)

15. With Rhodium.—1 pt. rhodium and 1 pt. steel form an alloy having a specific gravity of 9·176, and a very fine colour and surface for metallic mirrors; it does not tarnish in the air. An alloy of 1 pt. rhodium and 50 to 100 steel is very hard, tolerably tough, requires for tempering a temperature higher by 39° than common steel, and by 17° than Indian steel. (Faraday and Stodart, *loc. cit.* p. 329.)

16. With Silver.—Iron is said to take up a small quantity of silver when melted with it.

17. With Tin.—When iron and tin are heated to redness together, there is formed: *a*. An alloy of 22 pts. tin and 1 iron, somewhat harder than tin, and magnetic; and below it *b*. A compound of 2 pts. iron and 1 pt. tin (nearly FeSn), which is white, very hard, slightly malleable, and difficult of fusion: this constitutes *tinned Iron-plate*.—In cast-iron retorts in which the tin-amalgam used for silvering mirrors is continually distilled, for the purpose of regaining the mercury, an alloy of tin and iron is formed, amounting to between 1 and 2 per cent. of the tin obtained: when the tin is poured out of the retorts, this alloy partly floats upon it in scales, and is partly deposited at the bottom in the form of a doughy mass. It may be freed from the pure tin which adheres to it, either by boiling with hydrochloric acid, which dissolves the latter, or by treating it with nitric acid, by which the free tin is oxidised while the alloy is not attacked. When thus purified, it has the form of shining square needles, of specific gravity 8·733, brittle, and fusing at an incipient white heat. The powder of this compound, when thrown into the flame of a candle, burns with emission of sparks and a white smoke. It does not rust in the air, when moistened with water. It is not attacked by nitric acid at any temperature or any degree of concentration; it dissolves slowly in boiling hydrochloric acid; but rapidly and completely, and with violent action, in nitromuriatic acid. (Lassaigne, *J. Chim. méd.* vi. 609.)

Deville and Caron (Compt. rend. xlvi. 920) obtained the alloy FeSn, in broad shining laminæ, which were but slightly attacked by hydrochloric acid.

An alloy containing FeSn remains in the preparation of stannous chloride from Banca tin (see Tin), in slender (probably quadratic) needles of specific gravity 7·44, fusible only at a white heat; it solidifies in the crystalline form on cooling, and is then magnetic. The crystals are nearly insoluble in hydrochloric and nitric acid, but dissolve easily in nitromuriatic acid; they burn in the flame of a candle. (Nöllner, Ann. Ch. Pharm. cxv. 233.)

It has been proposed to harden malleable iron rails by introducing a portion of tin into the metal, but it has been found to render the iron extremely brittle and "cold short," and also incapable of being welded. (Karsten, *Eisenhüttenkunde*, i. 508, and Percy, *Metallurgy*, ii. 161.)

18. With Titanium.—Pig-iron often contains titanium (p. 335), which appears to be derived chiefly from the clay of the ore, or from other siliceous compounds added as fluxes. In three samples of grey pig from the iron ore of Westbury in Wiltshire, Riley found 1·15, 0·71 and 0·47 per cent. titanium. The titanium is either minutely disseminated through the iron or else alloyed with it. The presence of titanium in the ore or in the flux appears to improve the quality of the iron, and render it of excellent quality both for castings and for conversion by the Bessemer process; but according to Riley's observations, the titanium does not appear to remain with the iron, at least only in very minute quantity, when it is converted into bar iron or steel. Mushet has patented the use of titanium in the manufacture of iron and steel, and the alloying of titanium with iron and steel; but samples of his steel, in the manufacture of which titaniferous ores were used, did not yield any appreciable evidence of titanium. (Riley, Chem. Soc. J. xvi. 387; see *ante*, p. 335.)

19. With Tungsten.—Iron and tungsten may be united by fusion. It is stated that steel of very superior quality may be made by simply melting cast steel, or even iron, either with metallic tungsten or with the so-called native alloy, prepared by

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heating a mixture of powdered wolfram and fine carbonaceous matter in a lined with charcoal. (Bernouilli, Pogg. Ann. 1860, xxi. 573.)

ith Zinc.—Iron takes up zinc when heated with it. A brittle friable alloy y formed by melting zinc in vessels of wrought or cast iron, or by dropping melted zinc; sometimes crystalline compounds of ferruginous zinc are l. (Percy, *Metallurgy*, ii. 153.)

mersing malleable iron or cast iron, perfectly free from oxide on the surface, d zinc, the iron becomes covered with a coating of zinc, probably in conse- f the two metals being alloyed superficially. Iron thus coated with zinc is le to undergo oxidation when exposed to the atmosphere, and is largely l under the name of *galvanised iron*.

, BROMIDES OF. Iron unites with bromine in two proportions, form- *dibromide* or *ferrous bromide*, $FeBr^2$, and the *tribromide* or *ferric bromide*,

ous bromide is a yellowish substance obtained by passing bromine- ver gently ignited iron wire. It is soluble in water, and may be obtained ion by dissolving iron in hydrobromic acid, or in a mixture of bromine er. The solution yields by evaporation rhombic tabular crystals, contain- $r^2.6H^2O$. When exposed to the air it turns brown, and deposits *ferric ide*.

ic bromide, Fe^2Br^6, is produced by heating ferrous bromide with bromine, aporating to dryness a solution of iron in excess of bromine-water. It is a d mass which deliquesces in the air. It may be obtained in solution by g ferric oxide in hydrobromic acid, or by mixing the aqueous solution of the romide with bromine.

, CARBIDES OR CARBURETS OF. See Cast Iron (p. 329) and By heating alkaline ferrocyanides to redness, a compound of carbon and iron is , consisting of FeC^2.

other definite compounds of iron and carbon have been supposed to exist, viz. ^{3}, and Fe^4C, according to Karsten and Berthier (Ann. des Mines [3] iii. 229). cently Gurlt (Chem. Gaz. xiv. 230) has endeavoured to show that there is carbide, represented by the formula Fe^5C. The nearest approach to a definite d of carbon and iron is specular iron, which may perhaps consist essentially carburet; but the evidence of the existence of these compounds is exceedingly t.

, CARBONATE OF. See Carbonates, i. 784.

, CARBURETTED, ANALYSIS OF. It has already been mentioned iron contains, besides carbon, which is an essential constituent of it, a con- number of other elements, both metallic and non-metallic, that many of these are not completely removed in the processes to which the iron is subjected to t into bar iron and steel, and that all of them have more or less influence on the f the iron. It becomes, therefore, an important problem to detect these lements in iron, and, as far as possible, to estimate their amount.

on used for the analysis must be finely divided, as in the form of filings, or borings; very hard iron, such as specular iron, or hard steel, may be com- in a steel mortar, and sifted. The iron must of course be free from dust, rust, other foreign substances.

imation of the entire amount of Carbon.—To estimate the whole of the iron, both free and combined, the iron must be dissolved, without evolution gen, because that gas would carry some of the carbon with it; or the car- iron must be completely oxidised, and the carbon estimated as carbonic

carburetted iron is brought in contact with *chloride of silver*, *cupric chloride*, *chloride*, these compounds are reduced to metallic silver, cuprous chloride, and chloride respectively, while the metallic iron is also converted into ferrous which dissolves, and the whole of the carbon remains behind, together with nd various metals. The action of chloride of silver is very slow; the most con- eagent for this purpose is *cupric chloride*. A quantity of the iron (5 to 10 grms.) d with a moderately concentrated aqueous solution of cupric chloride, free from acid, whereupon metallic copper is precipitated, and ferrous chloride is formed. as trituration with a glass rod shows that the deposit is free from hard par- iron, the solution is decanted and the residue is drenched with a concentrated of cupric chloride acidulated with hydrochloric acid, in order to convert the copper into cuprous chloride, and dissolve it. The solution is then filtered a glass tube drawn out at the lower end to a narrow neck, and plugged with (or platinum-sponge), so as to retain all undissolved particles. Impure carbon

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is thus obtained, the weight of which may be determined by weighing the tu at 124°–130° C., both before and after the experiment.

Ferric chloride may also be used instead of cupric chloride, the free acid c in the solution being previously neutralised with carbonate of sodium or carb calcium. The basic ferric salt deposited in the reaction may be removed b hydrochloric acid or solution of ferric chloride.

The iron may also be dissolved, without loss of carbon, by nitric acid, provi first drenched with water, and then nitric acid free from chlorine or nitrous aci As soon as the solution has attained a sufficient degree of concentration, it is po the residue is drenched with fresh quantities of water and aqueous acid, and th yellowish solution, which contains nitrate of ammonia and nitrate of iron, i clarify, and finally filtered as above.

Another method is to heat the finely divided iron in a stream of dry *chlorine* viously freed from air by passing through a red-hot tube containing finely divided

Bromine or *iodine* may also be used instead of chlorine, and in the w Morfitt and Booth (Chem. Gaz. 1853, p. 358) drench the iron (not ver divided) with a small quantity of water, add iodine (*5* grms. to 1 grm. iron), a it for five or six hours, till the action is finished; then pour off the liquid, ac water and iodine, if any iron still remains, and filter. Care must be taken no too much water, and not to allow the action to go on too long, otherwise a p the carbon will be lost. The charcoal which remains after the solution of i iron has been filtered off, is washed with hot water, then with hydrochloric a again with water, and the residue is weighed.

The carbon obtained by either of these methods is not pure, but is mixe small quantity of iron, and a larger quantity of silicic anhydride and oxide o The amount of pure carbon may be determined, either by the loss which the sustains when ignited in contact with the air, or by burning the carbon as in analysis, with oxide of copper, or better with chromate of lead, or with a mixtur salt and chlorate of potassium, or in a stream of oxygen, and weighing the c carbonic anhydride by absorption in caustic potash.

Deville (Compt. rend. li. 938) separates the pure carbon at once by igni finely divided iron in a current of dry hydrochloric acid gas, quite free fro spheric air. The iron and all the foreign constituents, except the carbon, converted into volatile chlorides, and pure carbon remains behind.

2. ***Estimation of the Graphite or mechanically mixed carbon.***—This is the which remains behind mixed with silica, and sometimes also with humus-like compounds, when the iron is dissolved by dilute acids. To estimate it, the iron is d out by dilute hydrochloric acid of specific gravity 1·1; the washed residue is in potash-ley of specific gravity 1·1, to remove silica and humus-compounds, th water, then with hot hydrochloric acid, and lastly, with hot water, after whi dried, weighed and ignited in contact with the air, the loss of weight whic sustains being reckoned as graphite (Morfitt and Booth). Buehner (J. p lxxii. 364) washes the residue with boiling water, potash-ley, alcohol, and fina ether; then dries, weighs, and ignites as above. Gurlt (Polyt. Centralbla p. 378) treats the finely divided iron with recently precipitated chloride of si solution of sal-ammoniac, digests the residue with cyanide of potassium to chloride of silver, with potash to remove silica and combined carbon, then wi acid to remove metallic silver: the residue consists of graphite, which is to b as above.

3. ***Estimation of the combined Carbon.***—The carbon actually in combinat the iron is for the most part converted, during the solution of the metal, into hydrocarbons, which escape with the hydrogen, and impart to it a well-know sive odour; part of this carbon, however, always remains in the liquid form to the graphite. When carburetted iron is digested with *chloride of silv* chloride, or cupric chloride, as already described, the whole of the carbon behind, and on treating the residue with potash-ley, that which was origina bined with the iron dissolves, and may be separated, together with silica, b saturation with hydrochloric acid, evaporation to dryness, and washing. The of carbon in the residue thus obtained may then be determined, either by th weight sustained on ignition, or by combustion with chromate of lead. The c carbon is, however, more generally estimated by difference.

4. *Estimation of Silicon.*—The amount of this element may be deter igniting the residue obtained in the preceding operation; the carbon the away, and silica remains behind; as, however, a small portion of the carbon escape combustion, and the residue likewise contains a certain portion of slag, silica must be dissolved out by potash-ley of specific gravity 1·1 (which will n the slag), and then precipitated by supersaturation with hydrochloric acid.

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in a mixture of hydrochloric acid and air, carbonic anhydride, and the iron into volatile s mixed with the oxides of titanium, aluminium,

ilica in the residue left on burning the iron in ed by moistening this residue with concentrated ess, then digesting in dilute hydrochloric acid

itrogen may be detected in cast iron, according livided iron with potassium, perfectly cleansed phere of hydrogen quite free from air. The s, on addition of a ferroso-ferric salt and super- cipitate of prussian blue. According to Frémy, nto ammonia by ignition in pure hydrogen. gniting the pulverised iron with six times its baryta, receiving the ammonia thus evolved in o platinum-salt. Another method is to dissolve emains in solution; boil the liquid with excess in hydrochloric acid. A portion of the nitrogen ous residue, and may be determined by igniting nary way.

ulphur in pig iron may be converted into sul- id, but the quantity is generally too small to be hod is to convert it into sulphydric acid, by loric acid (which, of course, must not contain pass the evolved gas through a Liebig's bulb- olution of nitrate of silver, or through a series pper, or acetate of lead (the latter mixed with sulphide: 100 pts. sulphide of silver = 12·91 = 13·45 sulphur. As, however, the precipitated r arsenide, it is better to oxidise the sulphide ulting solution with chloride of barium.

e the pulverised iron with nitre and carbonate ydrochloric acid (silica then remaining undis- cid as a barium-salt. If the fusion is conducted at the mass does not pass over the edge of the ous acid in the flame, coming in contact with form an alkaline sulphate, which will greatly ur in the iron. If the fusion is made over a t arise. (D. S. Price, Chem. Soc. J. xvi. 51.) iven (pp. 332, 333), the estimation of sulphur are questionable are marked *.

ne iron (5 to 10 grms.) is dissolved in nitric or rated to dryness; the dry residue fused with line carbonate; the fused mass disintegrated by hydrochloric acid and evaporated to dryness in water; and from the filtrate the phosphoric sian phosphate. The acid filtrate may also be lphuric acid, the excess of baryta added being ing the phosphoric acid in the way just men- alumina, tartaric acid must first be added, to

may also be precipitated in the cold with car- sphorus is then thrown down as ferric phosphate, th alkaline carbonate and treated as above, or

once with a mixture of alkaline carbonate and bove described for the estimation of sulphuric ed from silica, may be used either immediately d, for the estimation of phosphoric acid.

, evaporates to dryness the solution of 1 grm. c gravity 1·2, moistens the mass with hydro- a quantity of water, that the filtrate measures tion of molybdic acid (prepared by dissolving pouring the quickly filtered liquid into 15 pts. n leaving the mixture to itself for a few hours at be collected on a weighed filter, washed with

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water containing 1 per cent. of nitric acid, and dried at 95°. 100 pts. of the dri precipitate correspond to 1 pt. phosphorus.

8. *Estimation of Arsenic.*—When arseniferous iron is dissolved in dilute hydr chloric or sulphuric acid, the arsenic is not given off as arsenetted hydrogen, but converted into arsenic acid (H. Rose), which remains dissolved if the solution h been made in the cold, but is precipitated from warm solutions not containing t great an excess of acid, as basic ferric arsenate, and is therefore often found in t carbonaceous residue.

When the iron is dissolved in nitric or nitromuriatic acid, the arsenic is convert into arsenic acid, and may be precipitated as basic ferric arsenate (together with pho phate) by boiling the solution with acetate of sodium, after the greater part of t ferric oxide has been reduced to ferrous oxide by heating it with sulphite of sodiu The precipitate is then decomposed by sulphide of ammonium, and the filtrate, acid lated, and treated with sulphydric acid, yields a precipitate of sulphide of arsen Or the iron may be dissolved in hydrochloric acid, with addition of a little nitric ac to dissolve all the arsenic; the filtrate heated with sulphite of sodium, to reduce the ferric to ferrous chloride; and the solution, freed from excess of sulphurous ac may be treated with sulphydric acid, with the usual precautions; the arsenic is th precipitated as trisulphide (together with the sulphides of copper and lead, if presen

As a portion of the arsenic sometimes remains in the carbonaceous residue, th residue must be examined, either by treating it with sulphide of ammonium, and pr cipitating the arsenic from the filtrate by sulphydric acid, or by fusing it with nitra and carbonate of sodium, and precipitating the arsenic as ammonio-magnesian arsena

The pulverised iron may also be fused with nitrate and carbonate of sodium, th silicic and sulphuric acids separated as above, and the arsenic then precipitated by su phydric acid, or if no phosphorus is present, by ammonia and sulphate of magnesiu

9. *Estimation of Manganese, Cobalt, Nickel, and Zinc.*—These metals may a be separated from iron, by precipitating the latter from a neutral solution in which the iron exists as ferric salt, with benzoate or succinate of ammonium, or from ac solution, with carbonate of barium.

10. *Estimation of Copper and Lead.*—The precipitate, thrown down as abo described by sulphydric acid from the reduced iron solution, sometimes contains trac of these two metals. The arsenic may be extracted from it by monosulphide of pota sium; and the residue, oxidised with nitric acid and treated with sulphuric acid, yiel insoluble sulphate of lead and a soluble copper salt.

11. *Estimation of Aluminium.*—For the method of separating this metal fro iron, see i. 155.

12. *Estimation of Magnesium, Calcium, and the Alkali-metals.*—The metals remain in solution after the iron has been precipitated as ferric oxide by be zoate or succinate of ammonium, or by carbonate of barium, and may be separated an estimated by the usual methods.

13. *Estimation of Chromium, Vanadium, Titanium, Molybdenum, an Tungsten.*—These metals occur especially in the black residue which remains wh pig iron is dissolved in dilute acids, and may be sought for either in this or directly the iron.

To detect and separate chromium and vanadium, a large quantity of the pulv rised iron is fused with 12 pts. nitrate and 1 pt. carbonate of sodium; the fused mas (which likewise contains silicic, phosphoric, and arsenic acids) is mixed with such quantity of nitric acid that it still retains a slight alkaline reaction, but does not giv off any nitrous acid (which would reduce the chromic and vanadic acids); the solutio is mixed with chloride of barium; the washed precipitate is treated with sulphur acid; the solution is saturated with ammonia and evaporated; and a lump of sal-amm niac is thrown in, whereby vanadate of ammonium is thrown down as a yellow white crystalline powder, while the chromate remains in solution. The vanadate ammonium, heated in contact with the air, yields dark red vanadic acid, the quantit of which can then be determined.

According to Sefström, the vanadic (and chromic) acid may be separated from th fused mass, after neutralisation with nitric acid, by the addition of a lead-salt; th washed precipitate is then boiled with strong alcohol and hydrochloric acid, the resultin blue solution of vanadic (and chromic) oxide, after being evaporated, is oxidise by nitric acid or chlorine-gas, then mixed with potash-ley, evaporated down, an fused; the fused mass is dissolved in water; and the vanadic acid is precipitated, as above, by sal-ammoniac. The liquid filtered therefrom (after separation of pho phoric and arsenic acids as ammonio-magnesian salts) yields with sulphydric acid precipitate of chromic hydrate, while sulphide of molybdenum remains in solution whence it may be precipitated by acids, and, when fused in a narrow tube, yields pur sulphide of molybdenum.

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ained by fusing the iron with nitre and soda, may
reated with chlorine-gas, which separates phos-
ated with nitric acid, afterwards with ammonia,
sal-ammoniac—or the fused mass is boiled with
r saturated with sulphydric acid gas (whereby
parated), and sulphide of vanadium precipitated
phovanadate by an acid.
ated from the liquid filtered from the vanadate of
ds, and most readily detected, after addition of
peroxide of hydrogen (i. 953). The chromic acid
kaline liquid, after neutralisation with nitric acid,
phosphoric and arsenic acids having first been
of magnesium (the addition of sal-ammoniac and
ney would precipitate the mercurous salt).
parates vanadium from pig-iron by dissolving the
nd after the iron is nearly all dissolved, adding
ne chloride of iron is then filtered off from the
washed from chloride of iron, and treated with a
the silica; the potash thoroughly washed out;
loric acid, washed until all the acid is removed,
a Bunsen's burner, or better in a muffle. The
ntly consisting of a mixture of a fusible and infu-
ucible yellow, and adhering strongly to it, some
ly blue colour, similar to the bloom of a plum.
with concentrated hydrochloric acid, gives off
vn solution, which on boiling soon becomes of a
black, finely pulverulent, insoluble residue. The
by evaporation, leaves a syrupy dark green mass,
ds a small quantity of white insoluble flocculent
green colour when acid, but blue when nearly
the characteristic reactions of vanadium-salts,
oming greenish on standing, with ferrocyanide of

with acid sulphate of potassium, forms a mass
er, and yields on boiling a dense yellowish-white
e reactions of vanadium-salts. The black powder
nd the soluble portion of the original residue
In a sample of grey pig iron from Westbury in
able quantity of phosphorus, part of which passed,
insoluble in dilute acids, Riley found—by sepa-
residue as magnesium-salt, and considering the
ntrated hydrochloric acid, as vanadic acid—that
the pig was 0·686 per cent.
in the carbonaceous residue left on dissolving pig
d out together with arsenic, by sulphide of am-
by acids: on heating the precipitate in a glass
ins behind.
the "bears" from copper furnaces (p. 367), may
the solution evaporated to dryness after addition
ed and precipitated by sulphydric acid, with ad-
of the molybdenum is thus precipitated, and may
solution in sulphide of ammonium, precipitation

acid [anhydride] when pulverised iron is heated
and oxygen; it then remains, together with silica,
dered soluble by fusion with carbonate of sodium.
acid, at last with aid of heat, and the solution is
ved in nitric acid, titanic anhydride remains, to-
may be rendered soluble as above.
n cold hydrochloric acid, the solution mixed with
tation of the iron by ammonia, and the whole of
l, copper, &c.) precipitated by sulphide of ammo-
olution, and may be precipitated and estimated by
der TITANIUM.
fter dissolving the iron in hydrochloric acid, col-
, treats the residue with dilute potash to dissolve
filter with hydrochloric acid, dries it at 250°, and

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weighs it. The weight of the residue, consisting of graphite mixed with t anhydride, being thus determined, the graphite is burnt off, and the dirty light b residue is fused with acid sulphate of potassium; the fused mass dissolved in water; and the solution boiled, whereupon titanic anhydride is precipitated n pure. Part of the titanium is, however, dissolved by the acid together with the hence, to obtain the entire amount, the solution obtained by fusing the residue the silica with acid sulphate of potassium must be added to the iron solution, the sulphur contained in it has been precipitated as a barium-salt, and the exc baryta removed. The solution in which the titanium and phosphorus are to b termined, is first reduced with sulphite of sodium, and the excess of sulphurous driven off. It is then nearly neutralised with ammonia, and acetate of sodiu ammonium added. If there is only a small quantity of phosphoric acid present, will always be sufficient ferric oxide to precipitate it; but if not, a few drops of acid must be added, and the solution boiled and filtered as quickly as pos This precipitate may be at once treated; or if it contains much ferric oxi excess of that sufficient to form phosphate of iron, it is better to redissolve hydrochloric acid, reduce it again with sulphite of sodium, and repeat the oper above described. The precipitate is then dissolved in hydrochloric acid, and chl of magnesium, ammonia, chloride of ammonium, and tartaric acid added, the pr tate produced being allowed to stand two nights; then the ammonio-magne phosphate is filtered off, dried, ignited, and weighed, and the phosphoric acid calcu from the pyro-phosphate of magnesium. The filtrate from the phosphoric ac treated with sulphide of ammonium, and the sulphide of iron separated, the fi evaporated to dryness, ignited, and burnt in a muffle; or evaporated nearly to dry transferred to a flask, and treated with fuming nitric acid until all the tartaric is destroyed; in either case, the residue is fused with acid sulphate of potassium. fused mass is dissolved in cold water, boiled for some hours, and allowed to st night in a warm place, when the titanic acid is filtered off and washed with sulphuric acid—dried, ignited, and weighed. If the determination of phosphori is not required, then the precipitate produced (either by one treatment or two) b alkaline acetate, may be dried (without washing), burnt, and fused with acid sul of potassium, and dissolved in cold water, whereby a little phosphate of iron, remains insoluble, is separated; and the solution being boiled, the titanic acid i cipitated, and may be separated as before. (For further details, see the paper referred to.)

Tungsten, which sometimes occurs in the residue of the solution of iron in h chloric acid, may be rendered soluble by fusion with alkaline carbonate, and sepa by precipitation with acids or with mercurous nitrate. It may be separated fro other constituents of the iron by the solubility of tungstic acid in ammonia, or sulphide in sulphide of ammonium.

14. *Estimation of the Iron.*—The amount of pure iron in carburetted iron is gen determined merely by difference, after all the other constituents have been estim It may, however, be estimated directly by Fuchs' method with metallic copper (p. or by any of the volumetric methods hereafter to be described. Mohr recom especially the use of two titrated solutions of chromate of potassium, one ten more dilute than the other (p. 384).

IRON, CHLORIDES OF. Iron forms with chlorine two compounds, anal to the bromides.

Ferrous Chloride, $FeCl^2$, is obtained in the anhydrous state:—1. By p chlorine or hydrochloric acid gas over iron filings or turnings heated to redne gun-barrel connected with a receiver into which the product may sublime.— heating iron-filings with sal-ammoniac, ferrous chloride then remaining beh 3. By boiling down a solution of iron in hydrochloric acid out of contact with t and heating the residue till the water is expelled.

Ferrous chloride crystallises in white or yellowish-white shining scales, according to Senarmont, are six-sided, and optically uniaxial; it has a specific g of 2·528, melts at a red heat, and sublimes when more strongly heated in a close Heated in an atmosphere of *hydrogen*, it is reduced, yielding hydrochloric aci pure iron crystallised in tubes. Heated in dry *air* or *oxygen gas*, it is resolve ferric oxide and chloride, the latter volatilising:

$$3FeCl^2 + O^3 = Fe^2O^3 + 2FeCl^3.$$

In contact with *aqueous vapour* at a red heat, it gives off hydrogen and hydro acid, and is converted into ferroso-ferric oxide:

$$3FeCl^2 + 4H^2O = Fe^3O^4 + 6HCl + H^2.$$

It absorbs *ammonia-gas* at ordinary temperatures, swelling up and crumblin

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powder, which, when exposed to the air, quickly takes up water and oxygen, is converted into ferric oxychloride and ferrico-ammonic chloride. Ferrous ide, heated to redness in dry ammonia gas, is converted into a nitride of iron, , containing 9·3 per cent. nitrogen (Frémy, Compt. rend. iii. 323). When d with a little charcoal powder, it is reduced by zinc-vapour at a red heat, yielding alline metallic iron, sometimes in dendrites, sometimes in tetrahedrons, and of fic gravity 7·84. (Ponmarède, Compt. rend. xxix. 520.)

rrous chloride exposed to moist air, absorbs water, and deliquesces. It dissolves r in *water* and *alcohol*, but is insoluble in *ether*. It dissolves in 2 pts. water at ° (Abl, Oesterreich. Zeitschr. f. Pharm. viii. 20); in 1 pt. of strong alcohol at . (Wenzel.)

drated Ferrous chloride, $FeCl^2.4H^2O$, is most easily obtained by dissolving iron ueous hydrochloric acid, finally heating the solution with excess of metal, and ing it at the boiling heat into a vessel moistened with strong hydrochloric acid. bluish-green liquid, left to cool in well-closed vessels, deposits the hydrated ide in crystals, which must be quickly pressed between paper and dried in air at t 30°. The bluish crystals are monoclinic, and cleave parallel to $\infty P\infty$ and $+P$. fic gravity, 1·937. The salt may be obtained as a crystalline powder by concen- ng the solution in a flask or a retort, and evaporating the concentrated liquid over ater-bath to a paste, stirring till it is cold. The crystals heated in a close vessel give off half their water, and the remainder at a higher temperature; when ly heated, they melt in their water of crystallisation; they effloresce at ordinary eratures when kept over oil of vitriol. They dissolve in 0·68 pts. *water*, easily in *ol* and, according to most authorities, in *ether*; according to Jahn, however, they soluble in ether. The solutions, especially the alcoholic, absorb *nitric oxide* gas, ssume a black-brown colour. The aqueous solution yields by *electrolysis*, iron and gen at the negative, chlorine and oxygen at the positive pole.

rrous chloride forms double salts with the chlorides of the alkali-metals. A ire of the concentrated solutions of ferrous chloride and *chloride of potassium* s, by cooling or slow evaporation, the salt, $K^2Fe''Cl^4.2H^2O$ or $2KCl.FeCl^2.2H^2O$, in blue-green monoclinic crystals. A similar *ammonium-salt* is obtained by mixing orresponding solutions, or by boiling iron filings with sal-ammoniac, hydrogen mmonia being then set free.

rric Chloride. *Trichloride of Iron*, Fe^2Cl^6, also called *Perchloride of Iron*, *sublimate*.—This compound is sometimes found in the craters of volcanos; it be obtained artificially by the following processes:—1. A piece of iron wire watch-spring introduced red-hot, or with a piece of burning tinder at the nto chlorine gas, burns with a red glow and forms ferric chloride, which then nes. The same result may be obtained by passing chlorine gas over gently d iron.—2. Ferrous chloride heated in chlorine gas is converted into ferric ide.—3. When ferrous chloride is heated in a vessel containing air, ferric chloride mes, and ferric oxide remains behind.—4. When an aqueous solution of ferric ide is evaporated, the dry compound remains behind, mixed with more or less ferric hloride; the dry residue, gently ignited in a loosely closed flask, yields the ferric ide sublimed in laminæ.—5. A mixture of 1 pt. calcined ferrous sulphate, and chloride of calcium, is ignited in a flask till the ferric chloride sublimes. (Baur, rt. Pharm. xxv. 432.)

rric chloride forms iron-black, iridescent plates, having a metallic lustre, and ilising and subliming somewhat above 100°. When heated in contact with *oxygen* it yields ferric oxide and chlorine; heated with aqueous vapour, it forms ferric e and hydrochloric acid gas. With *sulphuric acid* and with *sulphur*, it behaves ferrous chloride. (A. Vogel.)

ydrated Ferric chloride.—Ferric chloride dissolves in water with considerable ation of heat, and likewise deliquesces in the air. The liquid formed by deli- cence is called *Oleum Martis*. The same solution may be obtained by the wing methods:—1. By dissolving ferric oxide or its hydrate in boiling hydrochloric —2. By dissolving iron to saturation in a definite quantity of hydrochloric acid; ing the solution, and mixing it with half as much hydrochloric acid as it already ains; then heating the liquid to ebullition in a capacious vessel, and adding nitric in small portions, till the dark-brown colour first produced by the absorption of us gas has given place to a yellowish-brown, and the further addition of nitric produces no evolution of nitrous gas. The mixture is very apt to froth over, ially towards the end of the operation, when all the nitric oxide which has been rbed has been evolved. The same result may also be obtained by dissolving iron in muriatic acid; but it is not easy to hit the right proportion of the a ds.—3. By ng washed chlorine gas through aqueous hydrochloric acid saturated with iron, ng as the gas is absorbed. The dark brown liquid, which has a rough taste and

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colours the skin yellow, yields, on evaporating and cooling, crystals containing t perhaps three different proportions of water.

α. *Dodeca-hydrated*, $Fe^2Cl^6.12H^2O$ (with 40 per cent. water).—Ferric chloride quesces rapidly in the air, then crystallises in the form of this hydrate, and after deliquesces much less quickly (Kinast, Kastn. Arch. xx. 281). The same hy likewise separates slowly from an aqueous solution of the chloride not too muc centrated—fine radii stretching out in all directions from particular points, and fo pale orange-yellow, opaque, hemispheric nodules, into which the whole liqu ultimately converted. If the evaporation has been carried too far, the syrup wi crystallise unless it be exposed for some time to the damp air of a cellar, from it can absorb water. (Mohr. Ann. Ch. Pharm. xxix. 173.)

β. A *penta-hydrate*, $Fe^2Cl^6.5H^2O$ (with 21·7 per cent. water) is obtained by eva ing the liquid to a syrup, mixing it with a small quantity of strong hydrochloric to re-dissolve the precipitated ferric oxychloride, and leaving it to itself in the (Stein, Repert. Pharm. xiii. 264).—2. By fusing the crystals α, evaporating ti liquid becomes perfectly solid on cooling, replacing the lost hydrochloric acid leaving the solution to cool (Fritzsche).—3. The crystals α, placed beside vitriol, under a receiver containing air, soon deliquesce and form a thick liqu which large crystals then form, till the whole is converted into a mass of cr (Fritzsche, J. pr. Chem. xviii. 479). The 5-hydrate forms flat roseate or reddish-yellow crystals, which fuse readily, and solidify again at 42°; they a water from the air very rapidly, and with evolution of heat (Fritzsche). Whe crystals α and β are shaken together, a slight fall of temperature takes place, liquid is obtained—the same as that produced by imperfect evaporation of the cr α—which produces great heat when mixed with water (Fritzsche). 1 at. chloride dissolved in 9 at. water yields a liquid, which is identical with the *Martis* of the older chemists (as obtained by deliquescence of the solid chloride i air), has a density of 1·545, and refuses to crystallise. Hence there are two solu of ferric chloride in water to be distinguished; one containing more than 5 and less 12 at., the other containing more than 12 at. water.

Hex-hydrate, $Fe^2Cl^6.6H^2O$ (with 25 per cent. water)?—The hydrate is obt according to Wittstein, by leaving a solution of ferric chloride concentrated to a de of 1·50 in a covered plate, standing in a cool place, till it solidifies to a ma rhombic plates; also by evaporating to a syrup and leaving it in a covered vessel warm place. According to Gobley, Mohr, and Fritzsche, however, highly concent solutions of ferric chloride always yield the $\frac{5}{2}$-hydrate.

Hydrated ferric chloride dissolves easily in *alcohol* and *ether*, forming yellow tions, in which, however, if exposed to light or heat, especially in the ethereal solu it is easily reduced to ferrous chloride. Ether abstracts it from the aq solution.

Ferric chloride is also easily reduced to ferrous chloride by *zinc*, *stannous chl* *sulphurous acid*, *sulphydric acid*, &c. *Hydriodic acid* reduces the concentrated not very dilute solutions of ferric chloride. *Silver* and *platinum*, immersed in the tion, are converted into chlorides, reducing the ferric to ferrous chloride. The redu is likewise effected by many *organic bodies*. The reducing action of *tartaric ac* ferric chloride has been applied to photographic purposes by Poitevin. (Compt. lii. 94.)

A concentrated acid solution of ferric chloride yields by *electrolysis*, ferrous chl at the negative pole, while chlorine, and a small quantity of oxygen are evolved a positive pole. Liebig has suggested the use of this solution, instead of nitric in the zinc-carbon battery; the zinc, according to Buff, should then be immers solution of common salt. Such a circuit is, however, less powerful than th Bunsen.

Ferric chloride is much used in medicine; it is a powerful styptic, and is empl in the treatment of aneurisms and varicose veins. A few drops of the aqueous sol quickly coagulate albumin. (Handw. d. Chem. ii. [3] 607.)

Basic Ferric Chloride, or *Ferric Oxychloride*.—When a solution of ferric chlor evaporated, hydrochloric acid, resulting from mutual decomposition of the ferric ch and water, is always given off at a certain degree of concentration; at the same ti certain quantity of undecomposed ferric chloride volatilises, and a basic salt i consisting of ferric chloride with more or less ferric hydrate. The stronger the centration, the greater is the quantity of basic salt in the residue. The evapo mass no longer dissolves clearly in water, unless hydrochloric acid is added to reco the ferric hydrate into chloride. If the temperature be raised very high durin evaporation, a considerable quantity of ferric chloride is evolved, and a highly insoluble salt remains behind. A solution of ferric chloride heated to 300° in a s tube, deposits ferric oxide. (Senarmont.)

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of variable constitution are likewise obtained by ex-
ride to the air; by precipitating a solution of ferric
i not sufficient to take up the whole of the chlorine;
ith metallic chlorides, chloride of sodium for example,
, give off water, and afterwards ferric chloride, leaving

basic chlorides, are obtained by adding recently pre-
as ferric chloride. The hydrate dissolves in consider-
ution is formed, containing from 5 to 6 or 7 molecules
ne chloride. The solutions may be heated or diluted
; those which contain the larger quantities of oxide
on the addition of certain salts, and when evaporated,
lissolve in water. Compounds containing not more
are, on the contrary, perfectly soluble in water after
Mag. [3] viii. 406; Ordway, Sill. Am. J. [2] xxvi.
s. [3] lvi. 306; lvii. 296.)

ride of cyanogen, the compound $Fe^2Cl^6.2CyCl$, already
irectly with *pentachloride of phosphorus*, forming the
duced by the action of pentachloride of phosphorus or
tance, which melts easily, but is difficult to volatilise.

hlorides of the alkali-metals, forming double chlorides:
s are the most stable.

$H^4Cl.Fe^2Cl^6.2H^2O$.—A solution of sal-ammoniac in a
nen evaporated over oil of vitriol within a receiver
red monoclinic crystals, which may easily be mistaken
re not decomposed by water, like the corresponding
um (Fritzsche, J. pr. Chem. xviii. 484). By slowly
ature, L. Gmelin obtained very deliquescent rectan-
of the basal edges and four of the basal summits

of sal-ammoniac and 1 pt. of ferric chloride in water,
ransparent crystals, which, according to Geiger, are
contain a medium quantity of iron, but obtuse when
very small or very large; according to Marx also
o be made up of a very great number of small cubes
ther, whereby the cubical shape is somewhat altered.
nd variable. If 24 pts. of sal-ammoniac are used to 1
tals contain 0·85 per cent. of ferric chloride; if 14 pts.
ontain 1·93; and with 3 sal-ammoniac, they contain
. The mother-liquor of the last-mentioned crystals
own-red crystalline granules, containing 5·75 per cent.
When 10 pts. sal-ammoniac have been used with 1 pt.
ain 0·86 per cent of the latter (Winckler, Repert.
, when heated, become yellow and opaque, and evolve,
ds ferric chloride. They dissolve in 3 pts. of cold
rtion of ferric chloride does not exceed 5·12 per cent.,
; those which contain 5·75 per cent. Fe^2Cl^3, become
Repert. xiii. 422). When their aqueous solution is
llises out, nearly pure at first, but afterwards con-
st yellow and then red, and there remains a mother-

chloride and sal-ammoniac belong the *Ferruginous*
Salis-ammoniaci martiales. These are obtained:—
moniac with 1 pt. ferric oxide, whereupon ammonia is
gs, in which case hydrogen is set free and protochloride
uced; the latter, however, if the air has moderately
to ferrico-ammonic chloride, while ferric oxide is left
ture (obtained by evaporation) of 12 pts. sal-ammoniac,
m 1 pt. of iron filings.—3. By dissolving 16 pts. sal-
ide in water, and evaporating to dryness. Some phar-
preparation of the crystals above described. The
which is yellower and more deliquescent in proportion

$2NH^3.Fe^2Cl^6$, or *Chloride of Ferricum and Ferric-*
rric chloride slowly absorbs ammonia gas at common
ion of heat, but without alteration of external appear-

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ance. Part of the compound volatilises undecomposed when heated; the re ferrous chloride. It deliquesces in the air, but not so quickly as pure ferric When thrown into water in considerable quantities, it dissolves with a hissi and forms a dark red transparent solution. (H. Rose, Pogg. Ann. xxiv. 302

Ferrico-potassic Chloride, $4KCl.Fe^2Cl^6.2H^2O$.—A solution of chloride of pots excess of ferric hydrochlorate evaporated under a bell-jar over oil of vitriol, yie yellowish-red monoclinic crystals. A small quantity of water extracts chlorid from them, and leaves crystals of chloride of potassium undissolved, as may b examination with the microscope. A larger quantity of water dissolves th but, on evaporation, colourless crystals of chloride of potassium separate out afterwards coloured crystals of the ferrico-potassic chloride; and at this concentration, the crystals of chloride of potassium redissolve without any wa stirring, and are reconverted into crystals of ferrico-potassic chloride. (Fri J. pr. Chem. xviii. 483.)

Ferrico-sodic Chloride melts at 200°, forming a very mobile liquid. (Dev

Ferrico-ammonio-potassio-sodic Chloride—$4(NH^4; K; Na)Cl.Fe^2Cl^6.2H^2O$ (co 12·1 per cent. potassium to 6·2 ammonium and 0·16 sodium)—is found, toget sublimed ferric chloride, in the craters of volcanos, and remains, after the re the ferric chloride by deliquescence, in ruby-red regular octahedrons, which dried over oil of vitriol. It is very deliquescent, and difficult to recrystallise decomposition. (Kremers, Pogg. Ann. lxxxiv. 79.)

IRON, CYANIDES OF. (See CYANIDES, ii. 221.)

IRON, DETECTION AND ESTIMATION OF.—1. *Blow-p actions.*—Iron-salts fused in small quantity, with borax on platinum wir outer flame, colour the bead yellow while hot, the colour disappearing on With a larger proportion of iron, the bead is red while hot, and yellow after In the inner flame a bottle-green glass is produced. With phosphorus-salt, moderate quantity of iron-salt is added, the bead is reddish-yellow in the ou while hot, becoming yellow as it cools, then green, and finally colourless. large proportion of iron, the bead is deep red while hot, becoming red-brown green as it cools, and reddish-brown when quite cold. The colours change b much more quickly than those of the borax bead. These reactions are co ferrous and ferric compounds (H. Rose). Ferrous oxide in minerals may be distinguished by heating the substance for a very short time in the inner fl a bead of borax coloured pale blue by a small quantity of oxide of copper; th oxide then reduces the cupric oxide to cuprous oxide or metallic copper, whi red spots on the bead. The heat must not be too long continued, as in t ferric oxide, if present, would be reduced to ferrous oxide, which would then pr reaction just mentioned. To check this result, a portion of the substance may b for a moment in the oxidising flame with a new borax bead containing cop bead will then assume a pale green colour if ferric oxide is present, whereas oxide would produce the red spots in this case also. (Chapman.)

2. *Reactions in Solution.*

Some compounds of iron are soluble in water, and the greater number are s acids; many, however, especially native ferric oxide, and the artificially prepar after strong ignition, require prolonged boiling with strong hydrochloric acid to them. The solution of many iron ores, and of ferric oxide in a state of ve aggregation, may be facilitated by addition of zinc or stannous chloride, which the ferric to ferrous oxide. Many iron ores can be rendered soluble only by fusi with alkaline carbonates; some only by fusion with acid sulphate of potassium o

Iron usually exists in solution as a ferric or ferrous salt, or partly in one sta in the other; rarely as ferric acid, on account of the great instability of the that acid.

Ferric salts in solution are mostly yellow or reddish-yellow, more rare the case of the iron-alums) colourless or pale violet. *Sulphydric acid gas* pa the neutral or acid solution of a ferric salt reduces it to a ferrous salt, with prec of sulphur, thus:

$$Fe^2Cl^6 + H^2S = 2HCl + 2FeCl^2 + S.$$

In a solution of neutral or basic ferric acetate, however, sulphydric acid form precipitate of sulphide of iron; if, on the other hand, the liquid contains fr acid, nothing but a milky precipitate of sulphur is produced.

Sulphydrate of ammonium produces, in neutral solutions of ferric salts, precipitate of sulphide of iron insoluble in excess of the precipitant, and b red-brown by oxidation in contact with the air. If the quantity of iron presen

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inute, no precipitate is formed at first, but the liquid acquires a green colour, and if ept for some time in a closed vessel, deposits sulphide of iron in black flocks.

Alkalis and *alkaline carbonates* produce a red-brown precipitate of ferric hydrate soluble in excess of either of these reagents.

The *carbonates of barium, strontium,* and *calcium,* shaken up with a ferric solution, kewise form a precipitate of ferric hydrate.

Phosphate of sodium forms a white precipitate of ferric phosphate, which is turned ed-brown by alkalis, dissolves easily in nitric or hydrochloric acid, but is insoluble in cetic acid.

Ferrocyanide of potassium forms a deep blue precipitate of Prussian blue, insoluble acids, but dissolving in alkalis, with separation of ferric oxide. If the quantity of on present is very small, the precipitate appears green, or the liquid merely acquires green colour, and deposits blue flocks on standing.

Ferricyanide of potassium forms no precipitate, but changes the colour of the liquid greenish-brown. If the least trace of a ferrous salt is present, a blue precipitate is roduced.

Sulphocyanate of potassium changes the colour of ferric salts to deep blood-red, the oloration being very decided even in extremely dilute solutions: this is, in fact, the ost delicate of all tests for the presence of iron in the ferric state. The red colour is ot modified by addition of a small quantity of hydrochloric acid; but a large quantity early destroys it. A certain quantity of nitric acid destroys it completely after a hile, and it is not restored by subsequent addition of the ferric salt. The red colour is lso destroyed by oxalic, iodic, phosphoric, and arsenic acids, but reappears on again dding a solution of a ferric salt. Ammonia instantly decolorises the red solution and recipitates ferric hydrate. Sulphide of ammonium forms a black precipitate of ferric ulphide.

Infusion of galls colours ferric solutions deep blue-black, and renders them turbid. he precipitate is dissolved and the colour destroyed by free acids.

Ferric salts are easily reduced to ferrous salts by various *de-oxidising agents;* as by ulphydric acid, as already mentioned; by sulphurous, hyposulphurous, and phosphorous cids; by stannous chloride; by metallic iron, and even by silver at the boiling eat.

The reactions with sulphide of ammonium, alkalis, ferro- or ferri-cyanide of potas- ium, and sulphocyanate of potassium, serve to distinguish ferric salts from all other netallic salts.

Solutions of ferrous salts have a bluish-green or bluish colour, and, when xposed to the air, take up oxygen and are converted wholly or partially into ferric alts; and unless a sufficient excess of acid is present to form a neutral ferric salt with he quantity of iron present, part of the iron is precipitated in the form of a yellow- rown basic salt. They are likewise converted into ferric salts by *aërated water,* by *ypochlorous acid, nitric acid,* and by easily reducible metallic oxides and salts, such s those of *silver, gold,* and *mercury.* When nitric acid is the oxidising agent, the itric oxide separated from it does not escape from the liquid at ordinary temperatures, o long as any portion of ferrous salt remains unoxidised, but remains dissolved, forming dark greenish-brown solution.

A concentrated solution of ferrous sulphate or chloride placed in the circuit of a owerful voltaic battery, deposits metallic iron in small granules on the negative latinum wire. If the positive wire is dipped into a solution of common salt separated rom the iron solution by moist clay, the iron is obtained in glittering crystals which xhibit magnetic polarity (Becquerel). *Zinc* immersed in a perfectly neutral solution f ferrous sulphate or chloride contained in a stoppered bottle, throws down metallic ron (together with oxide) which is deposited partly on the zinc, partly on the con- iguous side of the glass. (Fischer, Pogg. Ann. ix. 266.)

Sulphydric acid forms no precipitate in a solution of ferrous salt containing an excess f one of the stronger mineral acids, but from a solution containing only a weaker acid, uch as carbonic, oxalic, tartaric, or acetic acid, it precipitates part of the iron, in the orm of a black hydrated ferrous sulphide, the precipitation in the three last-mentioned alts going on only till a moderate portion of acid is set free; the same reagent pre- ipitates ferrous benzoate, and even, to a slight extent, the sulphate and chloride, if he acids are completely saturated with base. From the sulphate or chloride mixed vith acetate of potassium, it throws down a considerable portion of the iron, but not he whole, even when the acetate is in excess. The black precipitate acquires a rusty rown colour by exposure to the air. It dissolves readily in hydrochloric or sulphuric cid, and likewise in a large quantity of acetic acid, provided it does not contain excess f sulphur.—The same precipitate, but containing the whole of the iron, is produced in ll ferrous salts, on the addition of an alkaline *sulphydrate,* and it is not soluble in an xcess of the reagent. A very dilute iron-solution to which sulphydrate of ammonium

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is added, assumes a green colour, from the presence of iron-sulphide in a sta suspension.

Fixed caustic alkalis completely precipitate the iron in the form of a white hyd which, by exposure to the air, acquires a dingy-green and afterwards a red-b colour.—*Ammonia* throws down part of the iron in the form of hydrate, the remaining dissolved in the liquid, which, when exposed to the air, becomes cov first with a green and afterwards with a brown film. If the ferrous salt is previ mixed with sal-ammoniac, ammonia yields no precipitate, but forms a pale-g mixture which exhibits similar appearances on exposure to the air.

Monocarbonate of potassium or *sodium*, and *sesquicarbonate of ammonium*, t down white ferrous carbonate, which soon acquires a green and afterwards a b colour by exposure to the air, and, if sal-ammoniac be added, dissolves in the li which then exhibits a green, and subsequently a brown turbidity on exposure t air. *Acid carbonate of potassium* or *sodium* forms the same precipitate, with evol of carbonic anhydride; but, if the solutions are dilute, a clear mixture is formed, v deposits ferrous carbonate on boiling, and on exposure to the air yields a precip of ferroso-ferric hydrate.—The *carbonates* of *alkaline earth-metals* do not precip ferrous salts. (Fuchs.)

Phosphate of sodium precipitates white ferrous phosphate, which acquires a bl green colour by exposure to the air.—*Arsenate of sodium* precipitates white fe arsenate, which becomes dingy-green on exposure to the air.

Oxalic acid and *acid oxalate of potassium* communicate a yellow colour to fe salts, and, after a while, throw down yellow ferrous oxalate, the precipitation i immediate when an alkaline oxalate is used.

Ferrocyanide of potassium forms a precipitate which is white, if the solution been perfectly freed from air by boiling and the iron-salt is absolutely free from oxide, but otherwise bluish-white: by exposure to the air, this precipitate is verted into Prussian-blue. *Ferricyanide of potassium* gives a deep blue precip (ii. 244), even in very dilute solutions.

Sulphocyanate of potassium neither alters the colour of ferrous solutions, nor f any precipitate in them.

Tincture of galls neither colours nor precipitates ferrous salts when they are free from ferric oxide; but the mixture acquires a violet-black colour on exposu the air.

The preceding reactions, especially those with the alkalis, and with ferrocya ferricyanide, and sulphocyanate of potassium, afford marked distinctions bet ferrous and ferric salts; it is but rarely, however, that ferrous solutions can be obt so pure as to give the reactions exactly as they are above described, exposure t air for a very short time being sufficient to convert a portion of the ferrous into salt: hence the precipitate formed by ferrocyanide of potassium is generally some bluish, and those formed by the alkalis have more or less of a dark-green t The best way of obtaining a solution of iron quite free from ferric salt, is to imm a few pieces of bright iron wire in aqueous sulphurous acid: a mixture of fe sulphite and hyposulphite is then formed, which gives a perfectly white precip with ferrocyanide of potassium.

Solutions containing both ferrous and ferric salts, such as are obtained by disso magnetic oxide of iron in hydrochloric acid, of course give reactions interme between those of pure ferrous and pure ferric salts; in particular, they give blue cipitates both with ferrocyanide and with ferricyanide of potassium; the formati both these precipitates in a solution obtained by dissolving a mineral in hydroch or sulphuric acid, without the addition of any oxidising agent, such as nitric may be taken as an indication that the mineral contains a mixture or compou ferrous and ferric oxides. From such mixed solutions, the ferric oxide may be cipitated by means of carbonate of barium, while the ferrous oxide will rema solution.

For the reactions of iron in the state of ferric acid, see ii. 637.

3. *Quantitative Estimation of Iron.*

Iron is always estimated by weight in the form of ferric oxide. If the solution tains ferrous oxide, either alone or mixed with ferric oxide, it is first boiled w sufficient quantity of nitric acid to convert the whole of the ferrous oxide into oxide, and then treated with *ammonia* in excess to precipitate the latter. The pr tate is collected on a filter, washed, dried, and ignited at a moderate red heat high a temperature expels a portion of the oxygen. Every 10 pts. of pure oxide correspond to 7 pts. of metallic iron. In some cases, however, it is nece to use *potash* as the precipitant. In that case, the precipitated ferric oxide is ver

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arry down with it a portion of the potash, which is exceedingly difficult to remove washing. It is best therefore, after having washed it two or three times with hot er, to redissolve it in acid and precipitate by ammonia. In other cases, as when the tion contains organic matter, the iron must be precipitated by *sulphide of ammonium*, use such substances prevent the precipitation of the oxide. To ensure complete ipitation, the liquid, after being mixed with excess of sulphide of ammonium, should eft for some time in a covered vessel standing in a warm place till it becomes quite urless or yellow, then filtered as quickly as possible, protecting it from the air, and precipitate washed with water containing sulphide of ammonium. The precipitated hide is then dissolved in nitric acid, and the iron precipitated by ammonia as before. the iron is mixed or combined merely with volatile or with easily combustible tances, its amount may be determined by simple ignition in contact with the air; he volatile and combustible matters will then be driven off or burnt away, and the will be left in the form of ferric oxide: to ensure its complete conversion into oxide, however, the residue should be moistened with nitric acid, and heated n.

n indirect method of estimating iron, given by Fuchs (J. pr. Chem. xvii. 160), nds upon the fact that metallic *copper* does not dissolve (or dissolves but very ly, and only when finely divided, ii. 40) in hydrochloric acid, if kept from contact the air, but when boiled with ferric chloride, it dissolves, with formation of us and cuprous chlorides:

$$Fe^2Cl^6 + Cu^2 = 2FeCl^2 + Cu^2Cl^2.$$

ne solution of ferric chloride mixed with excess of dilute hydrochloric acid and ed with water, is boiled in a flask, and clean copper-foil, not too thin (from 15 to ts. copper to 2 or 3 pts. ferric oxide), is completely immersed in the liquid; the is closed with a perforated cork, having a narrow glass tube passing through it, the liquid is boiled till it becomes permanently bluish-green or colourless. It is left to cool with the flask closed; decanted from the undissolved copper; this er washed by repeated affusion with hot water, and decantation, then dried between lous paper, and finally by heat, taking care not to rub it, and weighed. The loss eight multiplied by 0·883 gives the quantity of iron in the solution: for each atom pper (= 63·4) represents 1 at. iron (= 56) in the solution, and $\frac{56}{63·4} = 0·884$. Or oss of weight multiplied by $\frac{80}{63·4} = 1·261$ will give the quantity of ferric oxide ne solution. To ensure the complete reduction of the ferric to ferrous chloride, essential that the air be entirely excluded from the vessel, and therefore that the ng be kept up uninterruptedly till the liquid has become colourless.

lver in the spongy state may also be used to reduce the ferric chloride. The ucts of the reaction are ferrous chloride, which remains in solution, and chloride lver, which mixes with the metallic silver, and increases its weight. As in this ion, each atom of chlorine that enters into combination with the silver corresponds at. iron ($Fe^2Cl^6 + Ag^2 = 2FeCl^2 + 2AgCl$), the increase of weight multiplied by = 1·5774 gives the quantity of iron in the solution; or $\frac{80}{35·5} = 2·2535$ gives uantity of ferric oxide.

ne method of reduction by copper or silver may be applied to determine the quan- s of ferrous and ferric oxides, when they exist together in solution. The quantity rric oxide, or of iron existing as ferric salt, is first determined as above, the us salt present not interfering with the reaction. It is necessary, however, to d against the conversion of the ferrous into ferric salt by atmospheric oxidation: which purpose it is best to perform the determination in an atmosphere of nitrogen rbonic anhydride. Another portion of the solution is then treated with chlorine nvert the ferrous salt contained in it into ferric salt, and in this solution the total ntity of iron is determined by the same method. The difference of the two deter- ations gives the quantity of iron existing as ferrous salt.

errous and ferric oxides may likewise be separated by means of *carbonate of barium arbonate of calcium*, which precipitates ferric oxide from slightly acid solutions, not ferrous oxide. It is necessary to have the solution slightly acid, since if it is ectly neutral, a small quantity of ferrous oxide may likewise be precipitated. The tion, which should be slightly warmed, is shaken up with recently precipitated onate of barium (which acts more quickly than carbonate of calcium), in a corked k filled with carbonic anhydride; then left to stand, and shaken up again from e to time, till it has become quite colourless, afterwards filtered, and the precipitate hed, always in an atmosphere of carbonic anhydride. The precipitate, consisting

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of carbonate of barium mixed with ferric hydrate, is dissolved in dilute acid, the baryta precipitated by sulphuric acid, and the ferric oxide from by ammonia. This determines the quantity of iron existing in the solut *cum*. To find the quantity existing as *ferrosum*, the liquid filtered from tate of carbonate of barium and ferric oxide is boiled with nitric acid, to ferrous into ferric salts, then freed from baryta by sulphuric acid, and the cipitated as ferric oxide by treating the filtrate with ammonia. Or an of the original solution may be treated with nitric acid, to bring all the ferric state, and the total quantity of iron determined by precipitation wi The difference of the two determinations will then give the quantity of as ferrosum.

Anhydrous ferroso-ferric oxides may be analysed by dissolving them nitromuriatic acid, and precipitating the iron as ferric oxide by am proportions of iron and oxygen are thus determined, whence the for calculated.

Volumetric estimation of iron.—When iron is contained in a soluti oxide or ferrous salt, it may be estimated by determining the quantity of agent required to convert it into ferric oxide; if, on the other hand, it ferric oxide, the estimation may be made by measuring the quantity o agent required to bring it to the state of ferrous oxide.

1. *Methods depending on oxidation.*—The reagent most generally converting ferrous into ferric oxide in volumetric analysis is *permanganate* The method of applying it is fully described in the article ANALYSIS, (i. 263).—If the iron in the solution under examination is present wholly the method is directly applicable; if, on the contrary, the iron is pres partly as ferricum, it must first be brought to the ferrous state by he sulphurous acid or sulphite of sodium, or better with a few grains of pur mixture of ferrous and ferric salts, the ferrosum may be determined by portion with the permanganate directly, and another after reduction of t in the manner just described.

Acid chromate of potassium may also be used for the volumetric estim and has the advantage of not varying in strength when its solution is closed vessels. The reaction between ferrous oxide and chromic acid m sented by the equation:

$$\underset{\text{Chromic anhydride.}}{2CrO^3} + 6FeO = 3Fe^2O^3 + \underset{\text{Chromic oxide.}}{Cr^2O^3}$$

whence we find that 1 grm. of iron requires 0·8849 grms. of acid chromate $K^2O.2CrO^3$, to convert it from ferrous into ferric oxide. If, then, 8· the pure acid chromate are made into a litre (1000 cub. cent.) of soluti cent. of this solution will correspond to exactly 1 grm. of iron. The s acid chromate is slowly added to the acid ferrous solution till a drop of longer forms a blue precipitate with red prussiate. (Penny, Chem p. 599.)

Bunsen (Ann. Ch. Pharm. lxxxvi. 288) adds to the ferrous solutio hydrochloric acid, a weighed quantity of acid chromate, more than suffi complete oxidation of the ferrous salt, passes the chlorine evolved on he solution of iodide of potassium, and estimates the quantity of iodine thus the method described under ANALYSIS, VOLUMETRIC (i. 265). If no f were present, 1 at. $K^2O.2CrO^3$ would give 3 at. chlorine, and therefore but as a portion of the chlorine is used up in converting the ferrous into there will be 1 at. less of iodine set free for every 1 at. iron present as The quantity of iron x will therefore be given by the formula:

$$x = \frac{3Fe}{K^2O.2CrO^3} \cdot p - \frac{Fe}{I} a(nt - t')$$

where p denotes the weight of acid chromate used, and a, n, t, t' have the cations as in the article just cited.

For the exact estimation of iron in cast iron, iron ores, &c., Mohr use solutions, one containing 8·785 grms. of the acid chromate in a litre, th cent. = 0·01 grm. iron; the second diluted ten times as much, therefor = 0·001 grm. iron. A quantity of the substance, containing about 1 grm (that is to say 1·05 grm. pig iron, or 2·00 grms. iron ore, supposing the tain about 50 per cent. iron) is then weighed out, and dissolved in hydr the whole of the iron in solution is brought to the ferrous state by reduct &c.; the solution is then mixed with 100 cub. cent. of the stronger solutio

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afterwards added from a burette, till the liquid no
rricyanide of potassium.
ron is dissolved in acid, &c.; the solution is mixed
r chromate-solution; and as an excess of the latter is
rds with a graduated acid solution of ferroso-ammonic
on containing 7000 grms. of the crystallised salt
vith a small quantity of free sulphuric acid, so that
a blue colour is produced on addition of ferricyanide
c centimetres of this iron-solution used must of course
nmes of iron. (Mohr, Dingl. pol. J. clix. 124.)

tion.—Streng (Pogg. Ann. xciv. 493) dissolves the
lling hydrochloric acid; oxidises, if necessary, with
th cold water, after expelling the free chlorine, and
iodide of potassium, whereby iodine is set free:

$$KI = 2FeI^2 + 6KCl + I^2.$$

ous chloride is then added—whereby the brown colour
—and when only a small quantity of iodine remains
h-solution; then more stannous chloride, by drops,
f the tin-solution has been titrated with acid chro-
of metallic iron is given by the formula:

$$\frac{100 \cdot 6Fe \cdot c}{A.(K^2O.2CrO^3)} \cdot \frac{CG}{g},$$

id chromate in 1 c.c. of the standard solution of that
netres of tin-solution added to produce decoloration,
s of the same tin-solution used in determining its
entimetres of the chrome-solution used to oxidise the
the quantity of iron or ore dissolved.

257) after bringing the whole of the iron to the state
solution of ferrous chloride with artificially prepared
ng to expel free chlorine), adds a small quantity of
hen a standard solution of *stannous chloride*, till the
tion having been previously titrated with a solution
lution of ferric chloride under examination is mixed
m heated to 50° or 60°, and the standard tin-solution
Fresenius uses a solution of stannous chloride of
100 c.c. are required to reduce 1 grm. of pure iron
n ferric to ferrous chloride. He dissolves the iron or
l, oxidises with chlorate of potassium, and adds to the
quid, after all the free chlorine has been expelled, a
rather more than sufficient to decolorise it. The
starch-solution; and a solution of iodine and iodide
0·005 grm. iodine in a litre), previously titrated
ill a permanent blue colour is produced. The quantity
for the purpose gives the *excess* of tin-solution pre-

s chloride for the estimation of iron, it is essential
on-solution is diluted be free from air; otherwise a
e oxidised thereby.
in contact with *hyposulphite of sodium*, tetrathionate
th chloride of sodium and ferrous chloride, but no

$$\text{te} = 2FeCl^2 + 2NaCl + \underset{\text{Tetrathionate of sodium.}}{Na^2S^4O^6}.$$

248 parts crystallised hyposulphite of sodium
62·5 pts. ferric chloride; or 100 pts. iron, present as
ferrosum, 442·9 pts. of the crystallised hyposulphite.
ite of sodium in the same way as stannous chloride,
oride with iodide of potassium, a little hydrochloric
to 50°–60°, and adding the standard solution of
lisappears.
also be used for determining the proportions of ferric
me solution, one portion of the solution being titrated
all the iron has been converted into ferric salt; the
n existing as ferrous salt.

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4. *Separation of iron from other elements.*

From all metals of the first group (i. 217), iron is easily separated by *sulp acid*, which throws down all those metals, leaving the iron in solution. The which contains the iron in the form of ferrous salt, must then be heated with acid to oxidise the iron, which may afterwards be precipitated by ammonia.

The separation of iron from the metals of the second group, which are not preci by sulphydric acid from acid solutions, but are precipitated, together with i sulphide of ammonium from neutral or alkaline solutions, is more difficult.

From manganese (present as manganous salt) and from zinc, iron i effectually separated by *succinate* or *benzoate of ammonium*. The solution, af the iron has been brought to the state of ferric salt, is mixed with a sufficient q of sal-ammoniac to hold the manganese or zinc in solution, and very carefully neut with ammonia; it is then treated with benzoate or succinate of ammonium, which down the iron as ferric benzoate or succinate, leaving the manganese or zinc i tion. The precipitate is washed, dried, and ignited in an open platinum cruc that the air may have sufficient access to it, to prevent any reduction of the i the carbon of the organic acid. Should such reduction take place, the iron m reoxidised by nitric acid. The success of this mode of separation depends enti the care with which the acid in the solution is neutralised with ammonia before the benzoate or succinate. If too much ammonia has been added, manganese goes down with the iron; if too little, a portion of iron remains in solution addition of ammonia should be continued till a small quantity of ferric oxide cipitated, and does not redissolve on agitation. The supernatant liquid has deep brown colour, the greater part of the iron being still in the solution.

The separation of iron (as *ferricum*) from manganese and zinc may also be e by agitating the solution with *carbonate of barium* (as in the separation of ferri ferrous oxide, p. 383), which precipitates the iron as ferric oxide, leaving the metals in solution.

According to J. Schiel (Sill. Am. J. [2] xv. 275) manganese may be sep from iron by mixing the solution with *acetate of sodium*, and passing *chlorine* t it, which throws down the manganese as peroxide.

Zinc may be separated from iron (ferricum) when both are present as acetat solution containing a sufficient quantity of free acetic, but no inorganic acid, by p *sulphydric acid gas* through the solution, the zinc being then precipitated whi iron remains in solution. If the two metals are combined with any other acid must be precipitated by carbonate of potassium, and redissolved in acetic acid they are present as sulphates, they may be converted into acetates by decomp with acetate of barium.

For the methods of separating iron from cobalt, see vol. i. p. 1046. When t metals are precipitated together by sulphide of ammonium, the separation m effected by digesting the sulphides with acetic, as well as with dilute hydro acid; the iron then dissolves as acetate, while the cobalt remains behind.

Iron may be separated from nickel by the same methods as from cobalt (exc that with nitrite of potassium). Nickel may also be separated from iron (*fer* by mixing the solution with a large quantity of sal-ammoniac (20 pts. of that 1 pt. of nickel), precipitating the iron with *carbonate of ammonium*, then heati liquid slowly to the boiling point, keeping it at that temperature for some time, a small quantity of ammonia and filtering: ferric oxide then remains on the while all the nickel passes through in solution (Schwarzenberg, Ann. Ch. P xcvii. 216). Iron and nickel may also be separated by precipitating the iron as oxide with *carbonate of barium*. For the separation of iron from cobalt, this m is not so well adapted, because a small portion of the cobalt is apt to be precip at the same time.

Uranium may be separated from iron, both being in the state of sesquioxid treating the solution with excess of *carbonate of ammonium*, which precipitat ferric oxide, and retains the uranium in solution. The carbonate of ammonium however, be quite neutral, as if it contains any excess of carbonic acid, part of th may be redissolved. To ensure this condition, the carbonate of ammonium sho previously boiled, and the solution of the metals, if acid, must be neutralised ammonia till a slight permanent precipitate begins to form; the solution is to be diluted with water, the carbonate of ammonium added, and the preci digested with it for some time before filtering.

For the separation of iron from cerium, chromium, didymium, lantha molybdenum, niobium, platinum and its congeners, tantalum, titan tungsten, and vanadium, see those metals; also pp. 374, 375.

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luminium, iron in the form of ferric salt may be separated by caustic
ich when added in excess, and boiled with the concentrated solution of the
precipitates the iron as ferric oxide, and retains the alumina in solution.
portion of iron is small (not exceeding 1 pt. ferric oxide to 100 alumina),
d of separation is sufficiently exact; but when it is larger, a portion of the
lways remains with the ferric oxide, and must be separated by redissolving
itate in a small quantity of hydrochloric acid, and repeating the treatment
h. With very large quantities of iron, this treatment must sometimes be
hree or four times before complete separation is effected. The process may
d by first reducing the ferric solution with sulphurous acid or an alkaline
nd then boiling with potash till the iron is precipitated as dark green
ric oxide; but in this way also the separation is not quite complete; if too
hurous acid is added, a small quantity of sulphite of aluminium is sometimes
d on boiling.

d aluminium may, however, be much more easily separated by means of
ite of sodium, which precipitates alumina together with sulphur, leaving the
ution (i. 155).

very good method of separating iron and aluminium is to mix the solution
ntity of *tartaric acid*, sufficient to prevent the precipitation of the oxides
liquid is rendered alkaline, then add excess of ammonia, and precipitate the
phide by *sulphide of ammonium*. The same method serves to separate iron
us other metals, *e.g.* cerium, glucinum, magnesium, thorinum, yttrium, and

ium (or glucinum) may also be separated from iron by precipitating the
nd ferric oxide together with *ammonia*, and igniting a weighed quantity of
d and calcined precipitate in a stream of hydrogen. The iron is then
the metallic state, while the alumina remains unaltered. The loss of weight
quantity of oxygen which was combined with the iron, whence the quantity
xide may be calculated, and the alumina determined by difference. As a
he result, which is especially necessary when the quantity of iron is small,
e may be digested for 24 hours, without heating, in very dilute nitric acid
of specific gravity 1·2 diluted with more than 30 pts. water), which dis-
iron without attacking the ignited alumina. A slight loss may arise in this
consequence of particles of the alumina (or glucina) being carried over by
n of hydrogen (Rivot). Deville modifies this process by exposing the
f metallic iron and alumina, obtained as above, to a very strong red heat, in
f hydrochloric acid gas, whereby the iron is volatilised as chloride, while
na remains unaltered, and may afterwards be weighed; the iron is then
d by difference. Or the iron may also be directly determined by passing
r of boiling hydrochloric acid into the tube and attached receiver, in which
le of iron is condensed, oxidising the solution of ferrous chloride thus ob-
h nitric acid, and precipitating by ammonia.

glucina, and from most other protoxides, iron in the form of sesquioxide
parated by precipitation with carbonate of barium (p. 383).

magnesia, ferric oxide may be separated by precipitation with *ammonia* after
f sal-ammoniac—better with *succinate* or *benzoate of ammonium*, as already
for manganese (p. 386), or with *carbonate of barium*.

he alkalis and alkaline earths, ferric oxide may be separated by *am-*
the case of the alkaline earths, however, care must be taken not to add
a slight excess of ammonia, and to protect the precipitate from the air
tration and washing; otherwise carbonic acid will be absorbed, and earthy
s will be precipitated, together with the ferric oxide, and the precipitate,
ning, will appear light-coloured; it must then be redissolved in acid, and
ated by ammonia. If the solution contains any organic substance, the iron
recipitated by sulphide of ammonium (p. 383).

ation by ammonia serves to separate iron in the ferric state from most of its
salts, *e. g.* the nitrate, sulphate, &c. From phosphoric or boric acid it
parated by dissolving the salt in hydrochloric acid, adding tartaric acid in
quantity to prevent precipitation by alkalis, then adding excess of ammonia,
itating the iron by sulphide of ammonium.—For other methods of analysing
s of iron, see PHOSPHORIC ACID.

rsenic, iron may be separated by precipitation with *sulphydric acid*, the
r arsenate of iron being dissolved in hydrochloric acid. These salts may also
osed in the dry way, by ignition in a stream of sulphydric acid gas, sulphide
then volatilising, and sulphide of iron remaining. (See also p. 374.)

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5. *Assay of Iron ores.*

1. *In the wet way.*—From most ferruginous minerals that are actually used fo extraction of iron, viz. the oxides and carbonates, the iron may be dissolved ou boiling with hydrochloric acid, the insoluble residue consisting of quartz, clay, which may be further analysed by fusion with an alkaline carbonate.

The acid solution generally contains—besides iron—manganese, aluminium, cal magnesium, the alkali-metals, and small quantities of sulphur, phosphorus, ar silicium, and titanium, and less frequently copper, zinc, lead, vanadium, chrom molybdenum, and tungsten. These elements may be detected and separated by me already described, or to be described, under their respective heads (see also pp. 3 376). The last four, together with titanium, may be separated by fusing the pulve ore with a mixture of alkaline carbonate and nitrate, and treating the fused mass water, whereby a solution is formed, which may contain titanate, vanadate, chro molybdate, and tungstate of alkali-metal, together with silicate, arsenate, and phosp

If the whole of the iron cannot be extracted from an ore by boiling with h chloric acid, it must be pulverised and fused with carbonate or acid sulphate of a metal (bisulphate of potash), and the fused mass then dissolved in water or aq acid, freed from silica by evaporation, and further examined for the above-ment constituents.

In the complete quantitative analysis of iron ores, it is necessary to determin water and carbonic acid. The water may be estimated by igniting the ore in a tube, and condensing the aqueous vapour by means of chloride of calcium; the car acid by the method described under ALKALIMETRY (i. 119). When either wat carbonic acid is present alone, its amount may be determined by the loss of w sustained on ignition.

If the percentage of iron in the ore is the only point to be determined, the iron, being brought into the ferric state by oxidation with nitric acid, may be precipi by ammonia, or, if phosphoric and arsenic acids are present, by sulphide of ammo after addition of tartaric acid (p. 387). Alumina, if present, must be separated b of the methods already described. All the trouble of these separations may, how be avoided by adopting Fuchs' method of estimation with metallic copper, which correct results, provided all necessary precautions are taken to exclude the air, one of the volumetric methods already described.

2. *In the dry way.*—The object of this mode of assaying, which is an imitatio the small scale, of the process which goes on in the blast furnace, is to determine only the quantity of iron contained in an ore, or rather the quantity that ca extracted by smelting, but likewise the quality of the pig iron obtainable, and gene also that of the slag.

10 grms. of the finely-pounded ore are mixed with 3 to 10 grms. of anhydrous b (according to the proportion of the gangue); and the mixture is placed in a cru lined with charcoal (*creuset brasqué*),* and exposed in a powerful air-furnace portable blast-furnace—Griffin's blast gas-furnace (ii. 787), for example—to a grad increasing heat, raised at last to whiteness. After cooling, there is found in crucible, if the operation is successful, a well-fused regulus of cast iron, and above slag composed of borax and the materials of the gangue. The regulus must be fully freed from slag and weighed. It should have a grey colour without appearance of separated graphite. A large separation of graphite shows that the has been too great. If the metal is white, it is very fusible and probably con manganese; it is then imperfectly carbonised, or it contains phosphorus, arseni sulphur. The slag should not contain either globules of iron mechanically m (these, if present, must be separated from the pulverised slag by levigation, or b magnet), or iron chemically combined, which latter condition will be indicated green colour in the slag. The weight of the regulus is increased by the carbon w it contains, but, on the other hand, a small quantity of iron always remains in the and the two errors thus produced may, for the most part, be regarded as compens one another.

Sometimes powdered glass free from metal is used instead of borax, to increas fusibility of the gangue; or the ore to be assayed is mixed with the same kind of that is to be used in the actual smelting process—that is to say, with chalk, i

* To prepare these crucibles, a Hessian or Cornish crucible is lined with successive layers of a composed of fine charcoal powder mixed with water, the whole being well stamped with a w pestle. As soon as a layer has been well pressed, its surface must be roughened with a knife, s the next layer may adhere to it well; otherwise the layers will separate when heated. The cr having been thus filled with stamped charcoal, the portion which projects over the edge is rem a cavity with rounded bottom is made in the middle, and the sides and bottom of this cavity are po with a rounded glass rod

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onsists of quartz or clay, or with clay if the gangue is chiefly limestone. To approximately the quantity of flux required, a preliminary analysis may be 1. By gently igniting 10 grms. of the ore, to determine the amount of water and acid.—2. By exhausting another sample with very dilute nitric acid, to e, by the loss of weight after washing and heating, the amount of water, acid, and lime, taken together. —3. By boiling with hydrochloric acid till all s dissolved out, and weighing the residue, which consists of quartz and clay: of weight in this experiment, compared with that in the second, gives the f ferric oxide.

points being determined, 10 grms. of the ore are mixed with such a quantity of alk that the assay may contain 3 pts. chalk to 2 pts. clay (Regnault). A uantity of fluorspar or borax may likewise be added. For rich ores, Karsten rm. fluorspar and 1 grm. calcined borax to 10 grms. of ore; for the poorer grms. fluor and an equal quantity of chalk; and for very poor ores, the same, m. borax.

es not containing silica, a certain quantity of clay or quartz is added with the Or 10 grms. of ore are mixed with the following proportions of flux:

iron ore . . .	1 grm.	chalk and		2·5 grms.	fluorspar.
iron ore . . .	0·5 „	„		2·5 „	„
atite . . .	2·5 „	„		2·5 „	„
ematite . . .	2·0 „	„		2·0 „	„
ore . . .	2·5 to 3·0 „	„	2·5 to 3·0	„	„
on ore . . .	1·0 „	„	2·0 to 3·0	„	„

right proportion of flux has been added, and the proper temperature attained, nstituted regulus is produced (p. 388), together with a good slag, having a owish or sometimes violet colour, an enamel-like or sometimes glassy aspect, choïdal fracture. If the slag is stony or earthy, yellow, grey, or brown, with cture, it is too rich in bases; too great an excess of lime causes it to crumble en touched. If, on the other hand, there is an excess of silica, the slag is ore or less transparent, of green colour (arising from ferrous oxide), and very The results of a successful assay yield the requisite data for smelting on the e.

6. *Atomic Weight of Iron.*

omic weight of iron has been determined in several ways:—1. From the ferric oxide obtained by dissolving a known quantity of pure iron (harpsire) in nitric acid, precipitating with ammonia, &c., the small quantity of ntained in the iron being estimated and allowed for.—2. From the quantity tained by reducing a known weight of ferric oxide with hydrogen.—3. By g the volume of hydrogen evolved in the solution of iron in hydrochloric acid. n the quantity of chloride of silver obtained by precipitating a known quanre ferrous or ferric chloride with nitrate of silver. The following table exhibits s obtained by various chemists; the determinations are arranged in chronolor, and the bracketed numbers indicate the method employed:

* (1) . . . Fe = 27·12	Berzelius§ (1) . . . Fe =	28·03	
ac† (1). . . Fe = 28·36	Erdmann & Marchand‖ (2) Fe =	28·01	
(3). . . Fe = 28·27	Maumené¶ (1) . . . Fe =	27·98	
‡ (4) . . . Fe = 27·98		28·02	
and Norlin§ (1) . Fe = 27·94	Dumas** (4) . . . Fe =	28·10	
„ (2) . Fe = 27·99		27·99	

mber 27·12, deduced from the first experiments of Berzelius, was for many eived as the true atomic weight of iron, although Bucholz, some years d made a determination of the composition of ferric oxide, which now appears een nearer the truth. Berzelius was afterwards led to conclude that his first nts were affected with an error, arising from the action of the nitric acid on vessel used, and from subsequent experiments, in which platinum vessels loyed, he obtained the higher number 28·03. The whole number 28, which an of all the most trustworthy determinations, is now universally adopted as tomic weight of iron, on the supposition that the metal is univalent in the and sesqui-valent in the ferric salts, *e.g.* ferrous chloride = *FeCl*; ferric

Ann. vii. 313. † Ann. Chim. lxxx. 163. ‡ Phil. Trans. cli. 181.
Ch. Pharm. l. 432. ‖ Ibid. lii. 212. ¶ Ann. Ch. Phys. [3] xxx. 360.
. Ch. Pharm. cxiii. 26.

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chloride = Fe^2Cl^3. If, however, iron is supposed to be bivalent in the ferrou trivalent in the ferric compounds—which is the view now generally adopted, *e.g*

Ferrous chloride . .	$FeCl^2$	Ferric chloride . . .	$FeCl^3$
Ferrous oxide . . .	FeO	Ferric oxide . . .	Fe^2O^3,

then the atomic weight is Fe = 56. (See METALS, ATOMIC WEIGHTS OF; also i ii. 30.)

The equivalent of iron, that is to say, the quantity of the metal which re 1 at. of hydrogen, is, in the ferrous compounds, *e.g.* $FeCl^2$, equal to 28, and in the compounds, *e.g.* Fe^2Cl^6, or $FeCl^3$, it is $\frac{2}{3}$ of 28, or $18\frac{2}{3}$, which number is denoted (See EQUIVALENTS, ii. 403.)

IRON, FLUORIDES OF. *Ferrous fluoride*, FeF^2, is obtained by diss iron in aqueous hydrofluoric acid, and crystallises by evaporation, or as the so approaches saturation, in small, colourless, rectangular plates containing water, they give off without decomposition when moderately heated. The anhydrous fl is not altered by ignition, even in contact with the air, but the hydrated sal turns yellow on exposure to the air, and if quickly heated, oxidises partially, off hydrofluoric acid. The hydrated crystals dissolve slowly in pure water easily in acids. Ferrous fluoride forms with *fluoride of potassium* a soluble salt, $2KF.FeF^2$, which separates in granular crystals. (Berzelius.)

Ferric fluoride, Fe^2F^6, is obtained by dissolving ferric oxide or hydrate in a hydrofluoric acid, and separates on evaporation in pale flesh-coloured crystals. heated in a platinum crucible, over a lamp urged by a blast, it melts, som exhibiting on the surface small cubic crystals of the fluoride, while the fused ma a rose-red colour, perhaps due to the formation of a small quantity of ferric Ferric fluoride is isomorphous with fluoride of aluminium, somewhat more fusibl that compound, and equally volatile. (Deville, Compt. rend. xliii. 970.)

Ferric fluoride dissolves slowly but completely in water, forming a colo sweetish, astringent liquid. Its solution mixed with ammonia deposits a basic oxyfluoride, which, when dry, forms a rust-yellow powder.

Mixtures of the solutions of ferric fluoride and fluoride of potassium deposit, o cooling, colourless, crystalline, sparingly soluble double salts. If the solution ferric fluoride is added by drops to that of the potassic fluoride, the salt for $2KF.Fe^2F^6$, in the contrary case, $4KF.Fe^2F^6$. (Berzelius.)

IRON-GLANCE. *Specular Iron ore.* See IRON, OXIDES OF (p. 385); als (p. 338).

IRON, HYDRATES OF. See IRON, OXIDES OF (pp. 393—399).

IRON, HYDRIDE OF. The flame of hydrogen evolved by dissolving i dilute acids sometimes yields black spots when a cold piece of porcelain is held and has hence been supposed to contain a gaseous compound of iron and hydrog Fresenius and Schlossberger (Ann. Ch. Pharm. xliv. 264), and other che have shown that these spots are produced by phosphorus, and that the gas, perfectly freed from mechanical impurities, does not produce them. Cameron (News, ii. 181) has shown that no ferruretted hydrogen is formed by dissolvi alloy of iron and sodium in acids.

When ferrous iodide is treated with zinc-ethyl and ether, gas is evolved (con of hydride of ethyl and hydrogen), and the residue, after washing with ether, y hydride of iron, mixed with metallic iron, in the form of a black powd sembling metallic iron, and decomposing with evolution of hydrogen, in contac water, or when heated. (Wanklyn and Carius, Ann. Ch. Pharm. cxx. 74.)

IRON, IODIDES OF. *Ferrous Iodide*, FeI^2, obtained by heating or tritu iodine with a slight excess of iron filings, is a brown compound, which melts at heat, forms a grey laminar mass on cooling, and volatilises at a stronger he dissolves readily in water, and the pale green solution, which may also be directly by digesting 1 pt. iron and from 2 to 4 pts. iodine in water, yields evaporated in contact with iron, and protected from the air, green deliquescent cr containing $FeI^2.5H^2O$. Both crystals and solution, when exposed to the air quickly turn brown, from formation of oxyiodide, and separation of ferric hydra iodine. Ferrous iodide cannot, therefore, be easily kept unaltered, either in th state or in solution; it keeps best when mixed with a sufficient quantity of cr sugar or milk-sugar. For preparing the compound for medical use, Mohr recom that 1 pt. iodine be converted into ferrous iodide by trituration with iron and the filtered liquid mixed with 25 pts. of simple syrup, and the whole quickly evap down to 25 pts.; 20 pts. of this syrup contain 1 at. of ferrous iodide. It is

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vever, to prepare the compound fresh every time it is wanted, which is not difficult, the action is very quick.

The solution of ferrous iodide treated with alkaline carbonates, yields iodides of the ali-metals, and may be used for the preparation of those compounds.

Ferrous iodide easily dissolves an excess of iodine: on adding 1 at. iodine to 3 at. rous iodide, a brown solution is formed (containing Fe^2I^6), which, when mixed with bonate of potassium, yields iodide of potassium and black ferroso-ferric hydrate; s doubtful whether the brown solution contains iodated ferrous iodide, or a ferroso-ric iodide, analogous to the magnetic oxide.

Ferric iodide, Fe^2I^6, is not known with certainty, but appears to be formed when n is heated in excess of iodine-vapour. The resulting compound dissolved in ter, yields a brown-red solution, which reacts like that which is obtained by dissolv- iodine in ferrous iodide, as above, or by dissolving ferrous hydrate in hydriodic acid. these solutions, when exposed to the air, give off iodine and deposit ferric hydrate.

IRON, METEORIC. See p. 336.

IRON, NATIVE. See p. 335.

IRON NATROLITE. See NATROLITE.

IRON, NITRIDE OF. Iron heated to dull redness in a porcelain tube, and bjected to the action of ammonia gas, becomes white, brittle, and increases in weight about 12 per cent. The compound thus formed is supposed by Despretz (Ann. im. Phys. [2] xlii. 122) to be a nitride of iron; but it has not been analysed, and is pposed by some chemists to contain hydrogen. It dissolves in weak acids, with olution of hydrogen and nitrogen, and formation of ammoniacal salts. At a white at it decomposed, giving off its nitrogen. Hydrogen, at a red heat, withdraws the trogen, forming ammonia.

Sometimes the iron, after ignition in ammonia-gas, is found to be altered in physical pperties, and yet not to have increased in weight; in such a case, the combination of e nitrogen with the iron is but transient, but nevertheless appears to alter its mo-ular structure.

Nitride of iron is also produced when oxide of iron is ignited in ammonia gas; also minute quantity when nitrogen gas is passed over red-hot iron. (Pelouze et rémy. *Traité*, ii. 452.)

Respecting the controversy about the existence of nitrogen in steel, see STEEL.

IRON, NITROSULPHIDES OF. *Nitrosulfures de fer.* (Roussin, Ann. n. Phys. [3] lii. 285.)—Compounds produced by the simultaneous action of nitrites d alkaline sulphides on iron-salts. They contain nitric oxide, together with sulphide iron and sulphide of hydrogen or an alkali-metal, and may therefore perhaps be garded as analogous in composition to the nitroferricyanides (ii. 250), that is to say, sulphides of iron in which 1 at. sulphur is replaced by 2 at. *nitrosyl*, NO. They ntain in fact a disulphide of iron, FeS^2, in which the fourth, or sometimes the half, the sulphur may be supposed to be replaced by an equivalent quantity of nitrosyl. e analogy of the nitrosulphides to the nitroferricyanides is shown by the fact, that nen a solution of nitroferricyanide of sodium is completely decomposed by sulphydric d, and the solution boiled and evaporated, the residue contains dinitrosulphide of n, which may be reconverted into a nitroferricyanide by treating it with cyanide of tassium. A mixture of iron-salt and nitrite of potassium yields a nitroferricyanide nen treated with cyanide of potassium, and nitrosulphide of iron when treated with lphide of potassium. In neither of these classes of compounds can the iron be tected by ordinary reagents.

Dinitrosulphide of Iron, $Fe^3S^3H^2(NO)^4 = Fe^2S^3(NO)^2.FeS.(NO)^2.H^2S$, or Fe^3S^4 $O)^4.H^2S$.—This compound is prepared by dropping a solution of ferric chloride or sul-ate, with constant stirring, into a mixture of the solutions of nitrite of potassium and lphide of ammonium, heating the liquid to boiling, keeping it at the boiling heat for a w minutes, and filtering to separate sulphur; the deep-coloured liquid deposits crystals the compound on cooling.—Or 35 grms. ferrous sulphate dissolved in 0·2 litre of de-rated water is added to a solution of 21 grms. dry nitrite of potassium, and 16 grms. ystallised sulphide of sodium also in 0·2 litre of water, and the solution is boiled and tered. When a ferrous salt is used in the preparation, no separation of sulphur kes place. The crystals are purified by recrystallisation.

Dinitrosulphide of iron forms black, needle-shaped, oblique rhombic prisms, 2 mm. ng, more soluble in hot (about 2 pts.) than in cold water, easily soluble in alcohol, ood-spirit, amylic alcohol, and glacial acetic acid; they dissolve in all proportions in her, and deliquesce even in ether-vapour. The solutions are very deep-coloured, ste styptic at first, then persistently bitter; they remain unaltered in air containing mmonia, and may be recrystallised from alkaline solutions. When heated to 115°—0°, they give off reddish vapours, together with sulphur, sulphite of ammonium, and

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nitrite of ammonium, and leave iron in the residue; when quickly heated, th away. The compound is easily decomposed by mineral acids, with evolution of vapours, not by organic acids. Chlorine and iodine decompose it, with evolu nitric oxide and separation of sulphur. It is precipitated from solution by pot ammonia, much more slowly by soda. The crystals are decomposed by perma of potassium, peroxide of lead, and mercuric oxide. Many metallic salts pre the solution, with elimination of nitric oxide. Cyanide of potassium and cya mercury convert the crystals into nitroferricyanides.

The crystals are not decomposed by sulphide of ammonium, sulphydric acid or ferri-cyanide of potassium, or tannic acid, neither of these reagents givi indication of the presence of iron in them. Neither are they decomposed by potash or soda in the cold, but when heated therewith, they give off ammonia yield ferric hydrate, together with a filtrate which deposits the following comp

Sulphuretted Nitrosulphide of Iron and Sodium, $Fe^2Na^6N^2S^6O^2$ or $Fe^2S^3(NO)^2$ —This compound forms large black crystals having a very bitter taste, easily so water and in alcohol, but insoluble in ether. The crystals decompose at 120° solution is decomposed, with evolution of nitric oxide, by chlorine, iodine, or n oxide. It forms precipitates with metallic salts, the reaction being in som attended with evolution of nitric oxide. The solution yields crystalline compo addition of potash or ammonia, but is not altered by caustic soda; the cryst not altered by sulphide of ammonium or ferrocyanide of potassium, but with ferri of potassium they yield nitric oxide gas and prussian-blue.

Sulphuretted Nitrosulphide of Iron and Hydrogen, $Fe^2H^8N^2S^7O^2 = Fe^2S^3(NO)^2.4$ separates in reddish flocks, when the preceding compound is decomposed by ac gives off sulphydric acid and suffers further decomposition, even during washi

Nitrosulphide of Iron, $Fe^2S^3N^2O^2$ or $Fe^2S^3(NO)^2$, separates, with evolution phydric acid, when sulphuretted nitrosulphide of iron and sodium is decompose acid at the boiling heat. It is a black substance, which when freshly prepar dried, burns away like tinder, when set on fire. It decomposes spontaneously, sulphide of iron. It is insoluble in water, alcohol, and ether, but dissolves in potash, with partial decomposition and separation of ferric hydrate.

Nitrosulphids of Iron and Sodium, $Fe^2Na^2N^2S^4O^2.H^2O = Fe^2S^3(NO)^2.Na^2S$ Formed by evaporating a solution of nitrosulphide of iron in sulphide of sod 100°, and treating the residue with alcohol and ether. Crystallises in red black by reflected light; dissolves with deep red colour in water, alcohol, and et is insoluble in chloroform and in sulphide of carbon. The solution is precipit metallic salts, forming insoluble compounds in which the sodium is replaced other metal. Some of these precipitates are tolerably permanent, whereas oth silver precipitate for example, decompose quickly, with evolution of nitric oxid

IRON ORES. The ferruginous minerals containing sufficient quantities to be available for the extraction of the metal, have already been described (pp. 343). For the methods of assaying them, see p. 388.

The following mineralogical terms must here be noticed.

Argillaceous or Clay Iron Ore.—This term is applied to several ores consis oxide or carbonate of iron mixed with clay. The argillaceous carbonate is call ply "clay iron-stone;" anhydrous and hydrated ferric oxides with a similar adm are called "red clay iron-stone," and "brown or yellow clay iron-stone," respec

Azotomous Iron Ore, or *Kibdelophane*. A variety of ilmenite or titaniferou ore. (See TITANATES.)

Bog Iron Ore.—A brittle or loosely aggregated variety of brown hæmatite, oc in low marshy grounds. It proceeds from the decomposition of other species an takes the form of leaves, nuts, or stems, found in the marshy soil.

Brown Iron Ore.—Hydrated ferric oxide (p. 338).

Columnar Iron Ore.—Red clay iron stone, having a columnar structure.

Green Iron Ore.—Hydrated ferric phosphate. (See DUFRENITE, ii. 347.)

Jaspery Iron Ore.—A variety of red clay iron ore, having a large, flat conchoïdal fr

Lenticular Iron Ore.—A variety of red clay iron-stone having a flat granular str

Magnetic Iron Ore.—Ferroso-ferric oxide (pp. 337, 397).

Micaceous Iron Ore.—Specular iron ore with a micaceous structure.

Ochreous Iron Ore.—Red hæmatite, having a soft earthy consistence.

Octahedral Iron Ore.—Syn. with magnetic iron ore.

Pitchy Iron Ore.—A variety of red hæmatite.

Red Iron Ore.—Native ferric oxide (p. 337).

Sparry or Spathic Iron Ore.—Crystallised ferrous carbonate (i. 785).

Specular Iron Ore.—Red hæmatite having a perfect metallic lustre (pp. 338,

Titaniferous Iron Ore.—Ferric titanate. (See TITANATES.)

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forms two oxides corresponding with the chlorides, *le*, FeO, the *sesquioxide* or *ferric oxide*, Fe^2O^3, and nposition, called *ferroso-ferric oxides*, which may be vo just mentioned: the most important of these is Fe^2O^3. A *trioxide*, FeO^3, may be supposed to exist te of potassium, $K^2FeO^4 = K^2O.FeO^3$, but it has not

er found in nature in the free state, but may be on with carbonic anhydride, as ferrous carbonate ron ore, and in solution in chalybeate waters; also netic iron ore. It is not easily obtained in the pure th which it absorbs oxygen. According to Debray, e of equal volumes of carbonic anhydride and carbo-. According to Liebig, it is obtained, mixed with a rrous oxalate in a close vessel. The impure ferrous pyrophoric powder, which in contact with the air d into ferric oxide.

or *Ferrous hydrate*, is obtained by precipitating perfectly free from air, with potash-ley, also free from ed water. The hydrate is then precipitated in white decantation with recently boiled water, then dried and tly free from oxygen. Schmidt (Ann. Ch. Pharm. paration thus conducted, obtained the hydrate as a having a pale greenish colour, probably arising from to the air, even in the dry state, it quickly absorbs , even to ignition, and is converted into ferric oxide. by oxidation, first into greenish ferroso-ferric, then It reduces iodic acid, also platinum- and mercury-Bineau, in 150,000 pts. of water, forming an alkaline cids, forming ferrous salts, and absorbs carbonic r state, so that it cannot be dried in an atmosphere of

de and hydrate dissolve in acids, forming salts in nic, according as its atomic weight is 28 or 56: *e.g.*

$$^2HCl = H^2O + FeCl^2$$
$$I^2SO^4 = H^2O + FeSO^4.$$

rise produced by dissolving iron in dilute acids. The and phosphate, are obtained by precipitation. The e as a natural mineral (p. 339).

e and crystallisable, white in the anhydrous, pale e. The solutions are green or greenish-blue, have a te, and quickly absorb oxygen from the air, yielding rric salt, because the quantity of acid in the solution ferric salt, inasmuch as iron is trivalent in the ferric, lts; thus ferrous sulphate yields by oxidation a basic ntaining only 2 at. SO^4;

$$O^3) + O = Fe^2O^3.2SO^3,$$

$$O^4 + O = Fe^2\left\{\begin{matrix}2SO^4\\O,\end{matrix}\right.$$

rric sulphate has the composition $Fe^2O^3.3SO^3$ or

ain a volatile acid, give it up on ignition, leaving a , such as sulphuric or nitric acid, gives up its oxygen f the acid, such as carbonic acid, retains its oxygen n, either pure or mixed with ferrous oxide, if the acid

ts in solution, see p. 381.

nioxide or *peroxide of iron*. This oxide occurs in dely distributed, viz. 1. As specular iron ore also $R . \frac{4}{3}P2 . \frac{1}{4}R$ (ratio of principal to secondary te, in regular octahedrons.—3. As red haematite, , and stalactitic shapes, also lamellar and granular, y, forming the several varieties of red clay iron-stone

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(p. 340). It is formed by heating iron or its lower oxides and hydrates in contact with the air.

Ferric oxide may be obtained in small crystals by decomposing ferric chloride with lime at a red heat (Daubré, Compt. rend. xlix. 143); in micaceous laminæ by heating the amorphous oxide with borax, and treating the resulting mass with hydrochloric acid (Hauer, Wien. Akad. Ber. xiii. 456), or by melting the amorphous oxide with chloride of calcium (Kuhlmann, Compt. rend. lii. 1283). Rhombohedral or laminar crystals of ferric oxide are likewise obtained by igniting the amorphous oxide in a slow current of hydrochloric acid gas. (Deville, Compt. rend. lii. 1264.)

When equal parts of ferrous sulphate (green vitriol) and common salt are heated to redness, and the product exhausted by washing, ferric oxide remains in red-brown shining scales. When pulverulent ferric oxide is ignited with sal-ammoniac, part of it becomes crystalline, while another portion volatilises as ferric chloride.

Ferric oxide is obtained in the amorphous state by igniting ferrous sulphate with $\frac{1}{12}$ pt. of saltpetre, and lixiviating the product; by dissolving iron in nitric acid, evaporating, and heating the resulting nitrate to redness; also by deflagrating iron filings with saltpetre. In the distillation of fuming sulphuric acid from green vitriol, a residue of impure ferric oxide is obtained, formerly known as *Caput mortuum vitrioli*. Amorphous ferric oxide is usually prepared for pharmaceutical use by igniting ferric hydrate or ferrous carbonate in contact with the air; the preparation thus obtained is called *Crocus Martis adstringens* or *Ferrum oxydatum rubrum*. Very pure ferric oxide may be prepared by heating ferrous oxalate in contact with the air; the salt then takes fire and is completely converted, without further heating, into ferric oxide. (A. Vogel.)

Ferric oxide prepared by either of the latter methods, is amorphous, and has a brown-red, red, or nearly black colour, according to the particular mode of preparation adopted. It is very hygroscopic, not magnetic, very hard, and is therefore used as a grinding and polishing material. The specific gravity of the artificially prepared oxide is 5·04 to 5·17 (H. Rose, Pogg. Ann. lxxiv. 440); that of red hæmatite and specular iron ore, from 4·5 to 5·3; of some columnar varieties as low as 4·2; that of martite from Peru, 3·80; from Puy de Dome, 4·65; from Brazil, 4·80 (Breithaupt); from Monroe, New York, 5·33 (Hunt). Hardness of hæmatite and specular iron ore = 5·5 to 6·5; of martite = 6. The cubic expansion of ferric oxide = 0·00004 for 1° C. (Kopp). Ferric oxide is not volatile, but at a full white heat it gives off oxygen, and is partially converted into ferroso-ferric oxide, which is attracted by the magnet.

Ferric oxide is reduced to the metallic state by *hydrogen gas*, at a heat even below redness, and completely at red heat by *charcoal* or *carbonic oxide*, also by *ammonia gas*. When ignited with *sulphur*, it yields sulphurous anhydride and a sulphide of iron. It easily gives up its oxygen when ignited with *combustible bodies*, but takes it up again when heated in contact with the air: hence it facilitates the combustion of organic bodies, and may be used for incinerating them (Gräger, Ann. Ch. Pharm. cxi. 124). Even at ordinary temperatures, it frequently acts as an oxidising agent in contact with organic matter, and is thereby reduced to magnetic oxide, or even to ferrous oxide, and then, by taking up carbonic acid, converted into spathic iron; the reduced oxide, if in contact with moisture, is frequently also reconverted into ferric hydrate (limonite or brown hæmatite) by atmospheric oxidation. The oxide is also sometimes further reduced by the action of *sulphydric acid*, and converted into pyrites: hence magnetite, limonite, and pyrites often occur as pseudomorphs after red hæmatite. According to Kuhlmann (Compt. rend. lii. 1169), it easily converts *sulphide of calcium* into gypsum at the expense of atmospheric oxygen; the oxysulphide of calcium of the soda-residues mixed with an equal weight of ferric oxide (the residue of the burning of pyrites), forms a very useful cement, which hardens quickly in contact with the air.

Ferric oxide dissolves in *acids*, but less easily in proportion as it has been more strongly ignited: the best solvent for it is strong boiling hydrochloric acid. The solution is facilitated by the addition of zinc or stannous chloride, the oxide then dissolving as ferrous chloride.

Ferric oxide, on account of its hardness, is much used as a grinding and polishing material. A very hard compact kind of red hæmatite, called bloodstone, forms, when well polished, the best material for producing a high lustre on coat-buttons, and on the gilding of porcelain. Ferric oxide in the pulverulent state is used for polishing gold, silver, and other metals, for polishing and sharpening cutting instruments, and for grinding and polishing glass for mirrors and lenses. According to Vogel (Dingl. pol. J. cxxxii. 275), the oxide obtained by the combustion of ferrous oxalate (p. 393) is peculiarly adapted for these purposes. That which is prepared by igniting green vitriol in crucibles is also much used, the least calcined portions, which are of a scarlet colour, forming *jeweller's rouge* for polishing gold or silver, and the more calcined portions, which are bluish or purplish, forming the *crocus* which

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teel. Lord Rosse prepares ferric oxide for polish-, by precipitating a pure dilute solution of ferrous the washed precipitate in a screw-press till nearly h appears dull red in the dark. (See *Ure's Dictionary*

olouring material for glass and porcelain, especially red, or when more strongly heated, an orange-yellow depending essentially on the mode of treatment; Mag. [4] xxxv. 439), ferric oxide may be made to he spectrum, according to the degree of heat applied.

Ferrichydrate, occurs abundantly in nature, either e iron ore (ii. 940), or in stellate groups of needles more frequently in stalactitic, botryoïdal or mammil-ubfibrous structure; also massive and occasionally r limonite; also mixed with clay, as brown or 338, 339). It is the colouring principle of many of mineral waters, of yellow sandstone, Turkish precipitation of ferric salts with alkalis or alkaline s are precipitated in like manner, and the precipitate rusting of iron, which takes place when the metal is rated by contact with small quantities of acids, and lly ammoniacal salts and urine.

epared by precipitating a moderately dilute solution mmonia (with a smaller quantity, a basic salt would er, to retain small quantities of ammonia, to remove imes with water, then dried, and washed completely his precipitate formed in the cold (the *Ferrum oxi-eias*) has the composition $Fe^2O^3.2H^2O$, according to Lefort (J. pr. Chem. liv. 305); $Fe^2O^3.3H^2O$, accord-1853, p. 367); or $2Fe^2O^3.3H^2O$, according to Péan s. [3] xlvi. 47), the proportion of water doubtless dilution, the mode of precipitation, and the tem-been exposed in drying. The hydrate precipitated (Lefort; Schaffner, Ann. Ch. Pharm. li. 117.) of various composition. Göthite is $Fe^2O^3.H^2O$; lerite, $Fe^2O^3.2H^2O$; and a variety of bog iron ore wgorod in Russia, consists, according to Hermann $Fe^2O^3.3H^2O$.

w to dark brown colour, and is sometimes a loose friable mass, according to the mode of preparation. asily soluble in acids, but its power of uniting with frequently even by prolonged immersion in liquids. tion of ferric hydrate is produced by boiling the H^2O (precipitated from the chloride by ammonia), . The colour then changes from ochre-yellow to ered is scarcely acted upon by strong boiling nitric ochloric acid. In acetic acid, or dilute nitric or rming a red liquid, which is clear by transmitted, precipitated by the smallest quantity of an alkali-n of strong nitric or hydrochloric acid, yields a red lves on diluting the liquid with water. The modi-an blue with ferrocyanide of potassium and acetic $O^3.H^2O$. This insoluble hydrate is likewise preci-inary hydrate in acetic acid is rapidly boiled. The ime at 100° C. in a close vessel, becomes light in lue with ferrocyanide of potassium, or exhibits any a sulphocyanate; strong hydrochloric or nitric acid, phuric acid, throws down all the ferric oxide in the éan de Saint-Gilles, Ann. Ch. Phys. [3] xlvi. 47.) its water between 80° and 100°, and the whole at a ydrated by heating it to 160°—200°, with a satu-n or chloride of sodium. (Senarmont.)

part of its oxygen to oxidable bodies, and is easily nnous chloride, &c. In contact with putrefying ith the air, it forms ferroso-ferric compounds, or as access to it, it quickly recovers the oxygen which substance, and can then again exert an oxidising

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action, thus acting as a carrier of oxygen from the air to the organic body: hence it accelerates the oxidation of woody fibre in the soil. (Kuhlmann, J. pr. Chem. lxxxi. 110.)

Ferric hydrate is rarely used alone in medicine; but in the recently precipitated state, it acts as an antidote to arsenic, as, when given in sufficient quantity, it forms a highly basic ferric arsenite, very difficultly decomposible by water.

Ferric hydrate unites with colouring matters, and easily fixes itself on many organic bodies, especially on tissues: hence its use as a mordant, and the formation of iron-mould on linen, cotton, &c. Such spots may be removed by oxalic acid, or acid oxalate of potassium, the action being greatly accelerated by contact with metallic tin.

Ferric salts.—In these salts, the iron may be regarded as trivalent, or the group Fe^2 as sexvalent, *e.g.* the chloride, Fe^2Cl^6; the nitrate, $Fe^2(NO^3)^6$; the sulphate, $Fe^2(SO^4)^3$. (The oxygen-salts may, of course, be regarded as compounds of ferric oxide with anhydrous acids, *e.g.* the nitrate, $Fe^2O^3.3N^2O^5$, the sulphate, $Fe^2O^3.3SO^3$.) Accordingly, it requires three molecules of a monobasic acid, such as nitric acid, to form a normal salt with one molecule of ferric oxide.

The normal ferric salts are for the most part soluble in water, and difficult to crystallise; some of them are deliquescent. They are mostly analogous in composition to the salts of aluminium, and frequently isomorphous with them; this correspondence of form and composition is most conspicuous in the alums; thus ferrico-potassic sulphate, $FeK(SO^4)^2.12H^2O$, is isomorphous with common alum, $AlK(SO^4)^2.12H^2O$.

Soluble ferric salts are obtained by dissolving ferric oxide or its hydrates in aqueous acids, or by oxidising ferrous salts with nitric acid, adding the quantity of acid required to form a normal ferric salt; *e.g.*:

$$2FeSO^4 + O + H^2SO^4 = Fe^2(SO^4)^3 + H^2O.$$

The insoluble salts are obtained by double decomposition.

Ferric salts are white in the anhydrous, yellow or yellowish-red in the hydrated state. The solutions have also, for the most part, a yellowish-red colour, especially when heated; the solutions of the nitrate and fluoride, however, are colourless; that of the chloride is brown-red, and those of the acetate, meconate, and sulphocyanate are blood-red.

The presence of free hydrochloric acid in a solution of ferric chloride changes the colour of the solution to orange yellow; this coloration, like that of other acid solutions of ferric salts (*e.g.* ferric sulphocyanate), is completely destroyed by addition of a sufficient quantity of phosphate of sodium; on the other hand, the colouring power of ferric chloride, in presence of an excess of strong hydrochloric acid, is very great, the bright yellow colour of commercial hydrochloric acid, for instance, being caused by a quantity of ferric chloride too small to impart a perceptible colour to the liquid when somewhat diluted with water.

Ferric oxide has a great tendency to form basic salts, which may be regarded as compounds of the normal salts with excess of ferric oxide: thus, besides the triacid or normal sulphate,

$$Fe^2O^3.3SO^4 = \ddot{Fe}^2(SO^4)^3 = \left.\begin{matrix}(S\ddot{O}^2)^3\\ \ddot{Fe}^2\end{matrix}\right\} O^6,$$

there are several basic sulphates, viz.

Sexbasic, $6Fe^2O^3.SO^3 = \left.\begin{matrix}S\ddot{O}^2\\ \dddot{Fe}^{12}\end{matrix}\right\} O^{19}$ or $17Fe^2O^3.Fe^2(SO^4)^3$

Quadribasic, $4Fe^2O^3.SO^3 = \left.\begin{matrix}S\ddot{O}^2\\ \ddot{Fe}^8\end{matrix}\right\} O^{13}$ or $11Fe^2O^3.Fe^2(SO^4)^3$

Tribasic, $3Fe^2O^3.SO^2 = \left.\begin{matrix}S\ddot{O}^2\\ \dddot{Fe}^6\end{matrix}\right\} O^{10}$ or $8Fe^2O^3.Fe^2(SO^4)^3$

Dibasic, $2Fe^2O^3.SO^3 = \left.\begin{matrix}S\ddot{O}^2\\ \dddot{Fe}^4\end{matrix}\right\} O^7$ or $5Fe^2O^3.Fe^2(SO^4)^3$

Monobasic, $Fe^2O^3.SO^3 = \left.\begin{matrix}S\ddot{O}^2\\ \ddot{Fe}^2\end{matrix}\right\} O^4$ or $2Fe^2O^3.Fe^2(SO^4)^3$

Sesquiacid, $2Fe^2O^3.3SO^3 = \left.\begin{matrix}(S\ddot{O}^2)^3\\ \dddot{Fe}^4\end{matrix}\right\} O^9$ or $2Fe^2O^3.2[Fe^2(SO^4)^3]$

Diacid, $Fe^2O^3.2SO^3 = \left.\begin{matrix}(S\ddot{O}^2)^2\\ \ddot{Fe}^2\end{matrix}\right\} O^5$ or $Fe^2O^3.2[Fe^2(SO^4)^3]$

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soluble in water, and are precipitated on heating a
ıtral solution of the corresponding normal salt (*e.g.*
e solution of a normal ferric salt, a quantity of alkali
hole.

acids are decomposed by ignition, leaving a residue
metallic iron, according to the nature of the acid
re the blowpipe and in solution, see page 380.

Hydrates.—The term ferroso-ferric is applied to
liate in composition between ferrous and ferric oxide,
ds of the two. The principal of these intermediate
the magnetic oxide.

Fe^2O^3.—When iron is heated to redness in the air,
ed, which may easily be separated. The inner layer,
ous, brittle, and attracted by the magnet. The outer
f ferric oxide, but in variable proportion; it is of a
brittle, yields a black powder, and is more strongly
e inner layer. The amount of ferric oxide in the
per cent., and on the very surface it is as much as
. Ann. vi. 35; also Schw. xlvii. 81). The specific
P. Boullay). Berthier (Ann. Ch. Phys. [2] xxvii.
s the scale-oxide as $4FeO.Fe^2O^3$; Mosander attributes
e found by Berthier to the fact of Berthier having
ers together.

$\left.\begin{matrix}Fe'' \\ Fe^2)^{VI}\end{matrix}\right\}O^4 = FeO.Fe^2O^3$.—This oxide occurs abun-

is one of the richest and most valuable ores of iron,
per cent. of the metal (p. 337). It occurs in mono-
n being usually the octahedron, sometimes the rhom-
being modified as in figures 194, 195, 196, 199,
129, 130); twins also occur, like figure 319 (ii. 160).

$\left.\begin{matrix}Mg'' \\ Al^2)^{VI}\end{matrix}\right\}O^4$, gahnite, $\left.\begin{matrix}Zn'' \\ (Al^2)^{VI}\end{matrix}\right\}O^4$, zeilanite, $\left.\begin{matrix}Fe'' \\ (Al^2)^{VI}\end{matrix}\right\}O^4$,

ron ore, $\left.\begin{matrix}Fe'' \\ (Cr^2)^{VI}\end{matrix}\right\}O^4$, and other minerals in which the

likewise the sexvalent radicles Al^2, Fe^2, Cr^2, replace one
r into which other diatomic metals enter in various
n magnesium in pleonast and chlorospinel. Cleavage
t. The dodecahedral faces are commonly striated,
Much more frequently, however, it occurs massive,

produced when iron is heated to redness in aqueous
sac); when ferrous chloride is heated to low redness
m (Liebig and Wöhler, Pogg. Ann. xxi. 582); also
gg. Ann. xv. 622), when iron is burned in oxygen-gas
tained crystallised in octahedrons, by igniting ferroso-
h the air (Hauer, Wien. Akad. Ber. xiii. 456); also,
heating ferrous oxide in a slow stream of hydrochloric
liii. 199); by fusing ferric phosphate with 3 or 4 times
(Debray, *ibid.* lii. 985); and by heating ferrous sul-
in covered crucibles (Kuhlmann, *ibid.* lii. 1283).
764), by heating ferric fluoride with boric anhydride
ned the magnetic oxide in long needles, made up of
s. Ebelmen obtained crystalline magnetic oxide by
ilicate. Artificially prepared ferroso-ferric oxide is,
k mass, which yields an iron-black powder, and is

o contain ferroso-ferric oxide, either free or combined
xample, according to Plattner (Ann. Ch. Pharm.
are laid beneath the hearths of iron-smelting furnaces,
e sometimes, in the course of 6 or 10 years, completely
e soil, into magnetic oxide, partly crystalline, partly
gnet (but not itself magnetic). The same compound
he refining hearths, where the iron comes in contact
Ueber krystall. Hüttenproducte, p. 17.)

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γ. Crystallised ferrous carbonate, ignited in close vessels, yields ferroso-ferri consisting, according to Krämer, of $FeO.Fe^2O^3$; according to Döberei $3FeO.Fe^2O^3$; according to Glasson, of $4FeO.Fe^2O^3$, the composition of the being doubtless influenced by the rapidity of the heating.

δ. The old pharmaceutical preparation called *Æthiops martialis*, is a ferros oxide, or mixture of ferrous and ferric oxides in various proportions, obtai oxidising iron in a current of aqueous vapour, or by partially reducing ferric ox ignition with iron filings, or with a quantity of oil just sufficient to make it moist powder; the preparation obtained by this last method always contains c

Ferroso-ferric oxide is easily reduced to the metallic state by ignition with hy charcoal, carbonic oxide, or ammonia-gas. When ignited in the air, it is co into ferric oxide.

Ferroso-ferric Hydrates.—These are compounds of various comp obtained by the partial oxidation of ferrous, or reduction of ferric hydrate, cipitating mixtures of ferrous and ferric salts with alkalis, and by the oxidation in contact with air and water.

α. *Dingy-green Hydrate.*—By exposing white ferrous hydrate to the air for time—or by precipitating a mixture of a ferrous salt and a small quantity of fer with potash or ammonia—a dingy-green hydrate of ferroso-ferric oxide is ob which, on further exposure to the air, is quickly converted into rusty-brown hydrate.

β. *Black Hydrate.*—1. This hydrate, which has nearly the composition $FeO + xH^2O$, is precipitated from a solution of magnetic oxide in hydrochloric a from a mixture of equivalent proportions of ferrous and ferric salts, on the a of potash or ammonia. The yellow solution of magnetic oxide in hydrochlori yields, with ammonia, a brownish-black precipitate, which is magnetic even w the liquid, so that it collects round a magnet dipped into that liquid. It r washed on the filter without becoming more highly oxidised (Liebig and W Pogg. Ann. xxi. 583).—2. The same precipitate is obtained by mixing ferrico-an sulphate with ferrous sulphate, in such proportion that the ferric oxide present mixture may contain three times as much oxygen as the ferrous oxide, and p tating with ammonia (Abich, Pogg. Ann. xxiii. 354).—3. Two equal porti ferrous sulphate are taken; the first is dissolved in water acidulated with sul acid, and oxidated at a boiling heat by the addition of nitric acid in small porti a time. The other portion is dissolved in water freed from air by boiling. Th solutions are then mixed; the mixture, while still hot, precipitated by ammonia at once in excess; and the liquid, together with the brown-black precipitate, hea so e minutes to the boiling point. The precipitated ferroso-ferric oxide is th lected on a filter and washed—during which process it undergoes further oxida and then dried at a gentle heat (Wöhler, Ann. Ch. Pharm. xxii. 56). This should yield $2FeO.Fe^2O^3$; but even if a greater quantity of ferric oxide is n duced by the nitric acid still remaining, or by contact with the air, the propor that oxide is sure to be increased by decomposition of water.—4. Böttger (*Be* ii. 12) precipitates ferrous sulphate free from ferric oxide by the addition of carbo sodium; washes the precipitate several times by decantation; and then boils tolerably concentrated caustic potash. This process yields a velvet-black p much less liable to absorb an additional quantity of oxygen than that which ha precipitated by ammonia.—5. Noel (J. Pharm. [3] i. 62) precipitates ferrous su with carbonate of sodium, washes the ferrous carbonate by decantation, leave drain upon linen, and then heats it in a cast-iron vessel, with constant stirring, is dry. It is thereby converted into a velvet-black powder. Soubeiran obtain this process a precipitate which was not perfectly black, and when treated with chloric acid, evolved carbonic anhydride.—6. Preuss introduces 4 pts. of pulv iron and 5 pts. of ferric oxide into a flask, together with a two or threefold quan water, and boils the liquid gently for some time. The mixture gives off fetid hy gas, and turns dark brown at first, but afterwards black. When the evolution ceases, and the resulting black powder settles down readily, it is separated by tion from the excess of iron; thrown on a filter of grey porous paper; and the after the water has drained off, is wrapped up in a large quantity of paper, and q dried in hot air. The black, very loose powder dissolves in acids without evolu gas, and the solution yields a black precipitate on the addition of an alkali. Th cipitate must not be dried by heat, because in that case it would turn brow higher oxidation. (Wöhler, Ann. Pharm. xxviii. 92.)

The black hydrate of ferroso-ferric oxide exhibits, after drying, the appear brown black, brittle, strongly magnetic lumps, having a conchoïdal fracture, and ing a dark-brown powder. It contains about 7 per cent. of water, which it gi when heated in a retort, leaving black anhydrous ferroso-ferric oxide. When

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ic oxide. From its yellow solution in hydrochloric
by ammonia (Wöhler).
erly much employed in medicine, but has now almost
odide of potassium from iodide of iron, it is advis-
such proportion (Fe^3I^8) that, on precipitating with
ferroso-ferric hydrate shall be formed, because it is
e, and therefore easier to wash.
drates dissolve in acids, forming brownish or yellow
other of the oxides predominates. These solutions,
o-ferric salts, are mere mixtures of ferrous and
rmediate between the two. They give black precipi-
ı ferro- and with ferri-cyanide of potassium, also
227), a reaction not produced either by ferrous or by

nhydride, FeO^3, is not known in the free state, but
errates (salts obtained by fusing iron or its oxides
potassium, $FeK^2O^4 = K^2O.FeO^3$.

r. Ferric oxybromide is obtained by evaporating
nide, or by treating it with a quantity of potash not
ı, or by exposing a solution of ferrous bromide to the

F. See page 378.

F. A ferric oxyfluoride is precipitated by ammonia
. (Berzelius.)

DF. The general properties of these salts have been
96). For the special descriptions, see the several

F. See page 401.

Phosphorus unites readily with iron, forming a grey,
ch takes a high polish. This compound, which has
pared by heating a mixture of phosphate of iron and
harcoal and placed in a forge fire.
ıorus produces a great alteration in the properties of
d (pp. 329, 334).

errum pulveratum ; Limatura ferri s. *Martis alco-*
for medical use may be prepared by mechanical
ınd subsequent boiling and straining. Iron-powder
this method in the Tyrol. The iron is, however,
livision, by reducing an oxide of iron with hydrogen.
5 ; cv. 192) mixes 1 pt. of ferrous sulphate perfectly
its weight of chloride of sodium ; heats the mixture
; washes the residue completely ; heats the ferric
ss in a glass tube or gun-barrel ; and passes over it
ctly free from carbon, sulphur, phosphorus, and
sent, would unite with the iron. It is difficult, how-
ed, to obtain iron quite free from sulphur ; hence,
ipitates ferrous chloride with ammonia, and reduces
ashed hydrogen-gas, avoiding the use of vulcanised
might take up sulphur from them). It is doubtful,
minute quantities of sulphur and carbon in the pul-
rious in its application. To preserve the iron from
led with hydrogen.
, slate-grey powder, which may be set on fire by a
y very quickly (mechanically pulverised iron cannot
ould be heated strongly enough in the hydrogen-
coming actually pyrophoric. It is much more active
, on account of its finer state of division.

Selenium in the state of vapour, passed over iron-
producing considerable evolution of light and heat.
ubstance, with metallic lustre, hard and brittle. It
off oxide of selenium, and forming a black brittle
errous selenite. (Berzelius.)
xii. 211), by passing selenium-vapour over red-hot
le product under borax, obtained a metallic-looking

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greyish-yellow, easily pulverisable compound, having a specific gravity of 6 the composition of ferric selenide, Fe^2Se^3.

IRON, SULPHIDES OF. Iron and sulphur unite directly with one under various circumstances, and in several different proportions. Besides t sulphides containing less than 1 at. sulphur to 1 at. iron, there is a *protosul ferrous sulphide*, FeS; a *sesquisulphide* or *ferric sulphide*, Fe^2S^3; a *disulphid* and a compound called the *magnetic* sulphide, intermediate in composition bet proto- and sesqui-sulphides. Metallic iron heated with excess of sulphur, yi or other of the four last-mentioned compounds, according to the heat appl degree of sulphuration being less as the temperature is higher. (Rammel Pogg. Ann. cxxi. 337.)

An **octoferric sulphide**, Fe^8S, is formed by passing hydrogen-gas over dibasic ferric sulphate (p. 396). It is a blackish-grey magnetic powder, whic treated with dilute acids, yields a mixture of 7 vols. hydrogen-gas and 1 phydric acid.

A **hemisulphide**, Fe^2S, is produced by heating anhydrous ferrous sulp hydrogen gas, half of the sulphur being then given off as sulphurous anhydrid a dark grey, coherent, magnetic powder, which dissolves easily in dilute acids off equal volumes of hydrogen and sulphydric acid. When ignited in sulphyd gas, it takes up sulphur and is converted into the protosulphide. It occurs, cc with other metallic sulphides, in many furnace-products obtained in the sme lead and copper ores.

Protosulphide, or Ferrous sulphide, FeS. This compound occurs i specimens of meteoric iron, sometimes imbedded in small yellow-brown masses times as a grey powder possessing metallic lustre. (Berzelius; Rammel Pogg. Ann. cxxi. 363.)

It has not been found in the free state as a terrestrial mineral, but exists in nation with sulphide of nickel, and mixed with copper-pyrites, in a massive, coloured mineral, with octahedral cleavage and specific gravity = 4·60, fron hammer, in Norway. This mineral, after deducting 5·14 per cent. of copper contains 36·7 per cent. sulphur, 41·1 iron, and 22·2 nickel, agreeing approx with the formula $2FeS.Ni^2S$. (Rammelsberg, *loc. cit.*)

Ferrous sulphide is produced: 1. By the direct combination of sulphur an either at a red heat, or at lower temperatures in presence of water.—α. Heat wire introduced into sulphur-vapour burns brightly, and forms ferrous sulp β. When iron filings are gradually heated in a covered crucible with about tw their weight of sulphur, the mass, when heated to about the temperature of l ness, begins to glow, and combination rapidly takes place, with vivid com throughout the entire mass.—γ. Sulphur pressed against a red-hot iron bar, pe it, and forms ferrous sulphide, which runs off in drops, and may be quenched in δ. Ferrous sulphide may also be obtained in the wet way by moistening a mix 28 pts. iron filings and 16 pts. sulphur, and applying a gentle heat; combinatio takes place, attended with considerable rise of temperature. When a consi quantity of mixture of 2 pts. sulphur and 3 pts. iron-filings is made into a pas water, and covered with earth, the mass after a while becomes red-hot, and giv large quantity of steam, which throws up the earth with violence, producing th of an artificial volcano.

2. By igniting ferric oxide or scale-oxide of iron with sulphur.—3. By heati pyrites, ferric sulphide, or magnetic pyrites, either alone to a bright red heat, c iron filings, or in an atmosphere of hydrogen.—4. By reducing ferrous sulph bright red heat in a crucible lined with charcoal. Ferrous sulphate is also red sulphide in the wet way by contact with decomposing organic matter.—5. By tating ferrous salts with alkaline sulphides.

Ferrous sulphide prepared in the dry way is a dense yellow mass with lustre, or sometimes a black porous mass. It is sometimes magnetic, but accor Berzelius, only when it contains a portion of one of the higher sulphides. It d alter sensibly by exposure to the air at ordinary temperatures, and is not deco by ignition, even to whiteness, in close vessels; but when gently heated in the a partly converted into ferrous sulphate; while at a stronger heat, sulphurous anhy evolved, and ferric oxide remains behind. With *nitric acid* it evolves nitro ferric oxide and sulphuric acid being formed, and sulphur separated. It disso dilute *sulphuric* or *hydrochloric acid*, with evolution of pure sulphydric acid g however, it is mixed with metallic iron, which is generally the case with the p phide obtained by igniting iron filings with sulphur, it gives off a mixture of sul acid and free hydrogen. *Aqueous vapour* passed over red-hot proto-sulphide converts it, with evolution of much hydrogen and sulphydric acid gas, into a bl

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gnetic mass. The water forms with the sulphide of iron, sulphydric acid and ide, which, by further decomposition of water, yields hydrogen gas and ric oxide; but a portion of the sulphur remains, even after three hours' Regnault, Ann. Ch. Phys. [2] lxii. 379). *Chlorine gas* does not decompose ide of iron; but that compound, when heated in the gas, yields chloride of d sublimed ferric chloride (H. Rose, Pogg. Ann. xlii. 540). Protosulphide ated to low redness with once or twice its weight of *carbonate of sodium* or fuses into a black, crystalline, highly magnetic mass, from which water ulphide of sodium or potassium, with a trace of sulphuric acid. *Baryta* and re in the same manner, only that the viscidity of the slag prevents the iron ng into a mass (Berthier, Ann. Ch. Phys. [2] xxxi. 170). When proto- f iron is fused with 30 times its weight of *protoxide of lead*, the whole of r is given off in the form of sulphurous anhydride, metallic lead is separated, d mixture of protoxide of iron and protoxide of lead is produced.

sulphide prepared in the wet way is a black amorphous substance, perhaps water; in the finely divided state, it has a dark green colour. In the moist xidises quickly on exposure to the air, being converted, first into ferrous hen quickly into yellow-brown basic ferric sulphate. It exhibits the same as the protosulphide prepared in the dry way, but is much more easily d, and dissolves much more quickly in acids, with violent evolution of acid gas.

ck mud at the bottom of drains, cess-pools, ponds and morasses, owes its sulphide of iron, probably formed by the putrefaction of organic matters in th ferric oxide contained in the soil.

sulphide or **Ferric Sulphide.** Fe^2S^3.—This compound is probably ient of copper pyrites, $Cu^2S.Fe^2S^3$ (ii. 77), and of magnetic pyrites). It is produced by heating iron to moderate redness, or ferric oxide to s with excess of sulphur: in the latter case, however, the product is mixed oxide, unless the process is several times repeated (Rammelsberg, Pogg. 339). According to Berzelius, it may also be obtained by the action of acid on ferric oxide at 100°, or on ferric hydrate at ordinary temperatures, ping a neutral solution of ferric sulphate into excess of sulphydrate of am- According to Rammelsberg, however, the product obtained by heating ferric lphydric acid gas to a temperature short of redness, is an oxysulphide con- . ferric oxide to 3 at. ferric sulphide; after stronger heating, the product contains oxide, but in place of it a certain quantity of ferrous sulphide; and if the ised to bright redness, there remains at last a sulphide of iron free from d having the composition of magnetic pyrites.

ulphide dried out of contact with air, is a yellow-grey, non-magnetic powder, ted to redness in close vessels, it gives off sulphur and leaves magnetic In the moist state it oxidises very quickly in contact with the air, especially ared by precipitation of ferric salts. Acids decompose it, with formation of t, evolution of sulphydric acid, and precipitation of sulphur.

o-ferric or **Magnetic Sulphide.**—This sulphide occurs native as mag- es, and is formed by heating iron with a slight excess of sulphur till the ; also by heating the disulphide to redness in a covered crucible. As thus it has a brownish-yellow to speiss-yellow colour; is attracted by the d sometimes itself magnetic. It does not lose weight when simply ignited ssels, but when heated in *hydrogen gas*, it yields sulphydric acid and the ide. Dilute *acids* dissolve it, with separation of sulphur and evolution of acid. Boiling *potash-ley* is said to remove a portion of the sulphur, leaving lphide.

tic pyrites or Pyrrhotin occurs in crystals belonging to the hexagonal l generally tabular, exhibiting the combinations oP . P, oP . ∞P, oP . ∞P . P, 239, 240 (ii. 139) and others. Ratio of principal to secondary axes = 1 : 1·741. P in the terminal edges of the pyramids = 126° 49′; in the lateral edges . Cleavage tolerably distinct parallel to oP, indistinct parallel to ∞P. More massive and amorphous, with granular structure. Hardness = 3·5 to 4·5. avity, 4·51 to 4·64 (Rammelsberg). Lustre metallic. Colour between low and copper-red. Streak dark greyish-black. Fracture small subcon- Brittle. Slightly attracted by the magnet. Tarnishes quickly. Before the t gives off sulphurous anhydride, and on charcoal in the outer flame, is into ferric oxide; in the inner flame it melts and continues to glow after the s removed. The mass, after cooling, is magnetic and has a metallic crystal- ure, with a yellowish colour on the fractured surface.

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The following are analyses of magnetic pyrites calculated to 100 parts deducting quartz, &c. (Rammelsberg, *loc. cit.*)

	H. Rose.	Schaffgotsch.	Rammelsberg.	Plattner.		Stromey
	a	*b*	*c*	*d*	*e*	*f*
Fe	61·56	61·17	60·66	60·20	60·29	59·2
S	38·44	38·83	39·34	39·80	39·71	40·7

	Rammelsberg.					
	g	*h*	*i*	*j*	*k*	*l*
Fe	59·21	60·00	60·83	61·03	61·30	60·1
S	40·79	40·00	39·17	38·97	38·70	39·9

a. From Bodenmais in Bavaria; *b*, from the same; *c*, from the same; Conghonas da Campo, Brazil; *e*, from Fahlun in Sweden; *f*, from Treseburg Harz; *g*, *h*, from Harzburg in the Harz; *i*, from Trumbull in Connecticut; Xalastoc in Mexico; *k*, *l*, from localities unknown.

These results may be included under the general formula, Fe^nS^{n+1}, in may have either of the values 5, 6, 7, 8, 9, 10; but the purest specimens agr nearly with the formula, $Fe^7S^8 = 5FeS.Fe^2S^3$, given by Berzelius, or with $6FeS.Fe^2S^3$.

Nickeliferous magnetic pyrites occurs crystallised or massive and of specific 4·543 to 4·674, in several localities. The following are analyses:

	Berzelius.	Scheerer.	Rammelsberg.			
	a	*b*	*c*	*d*	*e*	*f*
Fe	58·73	56·74	55·82	55·96	56·57	56·4
Ni	3·17	2·82	5·59	3·86	3·16	3·3
S	38·10	40·44	38·59	40·18	40·27	40·2
	100·00	100·00	100·00	100·00	100·00	100·0

a. Massive from Klefva in Småland, Sweden; *b.* Massive from Modum in N *c.* Laminar, intergrown with quartz and mica, from the Gap mine, Pennsy *d.* Massive, intergrown with white iron pyrites, also containing a small qua copper pyrites, from Horbach in Baden; *e.* Laminar, from Hilsen in Norway.

These analyses may be represented by the formula, $M^5S^6 = 3MS.M^2$ $M^6S^7 = 4MS.M^2S^3$, where M stands for Fe (56) and Ni (58·9), each metal being in both degrees of sulphuration. (Rammelsberg.)

Disulphide of Iron. FeS^2.—This compound occurs abundantly in in two distinct forms, viz. as *Yellow Iron pyrites*, *Cubic pyrites* or *Mundic* crystallises in monometric forms, and *White Iron pyrites*, *Marcasite*, *Radiated Spear pyrites*, *Hepatic pyrites*, or *Cellular pyrites*, which crystallises in t forms. Cubic pyrites occurs abundantly in rocks of all ages, from the crystalline to the most recent alluvial deposits, and has been found in small i crystals in the Vesuvian lavas. Marcasite occurs also in rocks of various age found in granite, gneiss, and mica slate, and abundantly in the plastic clay of th coal formation near Carlsbad in Bohemia. The peculiar circumstances whic mine the formation of one or other of these varieties are not known; neither ha found possible to convert the one into the other. Iron pyrites is often form iron salts, in presence of putrefying organic matters, such as straw, wood, sulphide of iron thus produced retaining the form of the organic substance.

Yellow iron pyrites occurs in a great variety of monometric forms, th nant forms being the cube, the octahedron, the trapezohedron 202 (*fig.* 180, the pentagonal dodecahedrons $\frac{2O\infty}{2}$ (*fig.* 192), and $\frac{3O\infty}{2}$, the hexakistetrahedr and $\frac{4O2}{2}$ (hemihedral forms of the hexakis-octahedron, ii. 127), these forms o either alone or in combinations, such as *figs.* 194, 195, 196, 211, and numerou Twin-crystals are also found resulting from the intersection of two pentagonal hedrons. Cleavage cubic and octahedral, more or less distinct; the cubic a hedral faces are often striated. It likewise occurs radiated, subfibrous, and r often reniform or globular, with a crystalline surface. Hardness = 6 to 6·5. gravity 4·083 to 5·031 (Dana); 5·0 to 5·2 (Rammelsberg). Lustre splendent; colour, bronze-yellow, nearly uniform. Streak, brownish black, Fracture conchoïdal, uneven. Brittle, strikes fire with steel. [For analy p. 343.]

White iron pyrites or marcasite forms trimetric crystals, in which *a* : 0·7454 : 1 : 1·1548. Angle $\infty P : \infty P = 73° 24'$; $\breve{P}\infty : \breve{P}\infty$ in the basal p

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= 98° 13'. The crystals are pyramidal and prismatic combinations, the faces
g frequently predominant in the latter. Cleavage tolerably distinct, parallel
It occurs also in globular, reniform, and other imitative shapes; often massive,
r, or granular. Hardness = 6 to 6·5. Specific gravity = 4·678 to 4·847
; 4·85 to 4·88 (Rammelsberg). Lustre metallic. Colour, pale bronze-
ometimes inclining to green or grey. Streak, greyish-black or brown-black.
uneven. Brittle.

hide of iron is produced artificially: 1. By heating iron with excess of
to a temperature below redness (Rammelsberg, Pogg. Ann. cxxi. 339).—
posing ferric oxide or hydrate, ferroso-ferric hydrate, or ferrous carbonate, at a
ve 100°, but not amounting to redness, to a stream of sulphydric acid gas,
s the mass continues to increase in weight. At first the action is so strong,
eous vapour, sulphurous anhydride, and hydrogen are evolved, and lower sul-
f iron are formed; but these afterwards take up more sulphur, and liberate
drogen gas. The sulphide of iron thus produced retains the crystalline form
xide used in its preparation, with the same lustre on the faces, and the same
s of cleavage (Berzelius).—3. The lower sulphides of iron may be brought
he highest degree of sulphuration, by heating them in like manner in sul-
acid gas (Berzelius).—4. An intimate mixture of 2 pts. protosulphide of
1 pt. sulphur, heated in a retort to a temperature short of redness, leaves
le of iron as a bulky, dark yellow, non-magnetic, metallic powder, not attacked
ochloric acid (Berzelius).—5. When an intimate mixture of ferric oxide,
and sal-ammoniac is heated to a temperature a little above that at which the
oniac sublimes, the residue is found to contain small, brass-yellow octahedrons
es, which may be separated from the rest of the powder by levigation (Wöhler,
nn. xxxvii. 288).—6. When sal-ammoniac containing sulphate of ammonium is
at a dull red heat in iron vessels coated with clay, the clay covering becomes
ated with chloride of iron, and cubes and octahedrons of iron pyrites form upon
ce (Löwe, *J. pr. Chem.* vi. 98).—7. The compound may also be prepared in
way by mixing solutions of alkaline persulphides with ferrous chloride at
ferrous sulphate at 165°. (Senarmont, Ann. Ch. Phys. [3] xxx. 129.)

ially prepared disulphide of iron differs in character according to the mode of
ion adopted, being either a bulky dark yellow powder (Berzelius), or crys-
in small brass-yellow cubes and octahedrons (Wöhler), or a black powder
mont). It is not magnetic, is not attacked by dilute acids, but is decomposed
ng with strong hydrochloric acid, with evolution of sulphydric acid, and sepa-
sulphur, and is oxidised when heated with strong nitric acid or with nitro
acid.

w iron pyrites in its compact forms, and the denser varieties of the artificial
le, do not alter by exposure to the air, and even that which is prepared in the
oxidises but slowly in the air, and only when moist; but white iron pyrites
very rapidly, and the yellow variety in the finely divided state oxidises even
ary temperatures, with sensible evolution of heat, as in the roasting of alum-
nd the spontaneous heating of coal or lignite containing pyrites, which some-
ecomes intense enough to set fire to inflammable substances, and gives rise to
taneous combustion of coal-mines. The products of this spontaneous oxidation
ong as the temperature remains moderate, sulphuric acid and ferrous sulphate,
eparates partly in crystals, partly as an efflorescence on the surface, but is for
part dissolved out by the water which permeates the mass (see SULPHATES);
higher temperatures, sulphurous anhydride is evolved, and ferric oxide is
h only a small quantity of sulphuric acid. This reaction renders iron pyrites
e for the manufacture of sulphuric acid (*q. v.*). When ignited with charcoal,
sulphide of carbon. Mixed with 10 per cent. charcoal, and exposed to the
f a mixture of superheated steam and atmospheric air, it is completely desul-
, giving off sulphur, sulphydric acid, and sulphurous anhydride, together with
anhydride and carbonic oxide, while the iron remains, according to cir-
ces, either in the metallic state or as ferric oxide. (Brunfaut, Journ. des
1861, No. 5.)

N, TANTALATE OF. See TANTALITE.

N, TELLURIC. A term applied to native metallic iron found on the earth's
to distinguish it from meteoric iron.

N, TELLURIDE OF. See TELLURIDES.

N, TUNGSTATE OF. See TUNGSTATES.

MIC ACID. $C^{16}H^{12}N^2O^4$. *Imasatic acid, Rubindenic acid.* (Laurent,
. Phys. [3] iii. 490.)—This acid is produced by the action of warm ammonia
n; but the best mode of preparing it is to dissolve isatin to saturation in

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aqueous potash; evaporate the solution to dryness; dissolve in alcohol; mix the solution with a very concentrated solution of sulphate of ammonium (in the proportion of rather more than 1 at. of that salt to 1 at. isatin); filter to separate sulphate of potassium; evaporate the filtered liquid to dryness, whereby the isatate of ammonium is converted into isamate; then boil with alcohol; filter to separate isamide and sulphate of ammonium; and neutralise the filtrate with hydrochloric acid, taking care to avoid an excess. Isamic acid then separates in crystals on cooling. If a small quantity of isatin should likewise separate, in consequence of too much hydrochloric acid having been added, or of too great a heat having been applied, or of the solution of isatate of ammonium not having been sufficiently evaporated, the crystals must be treated with weak ammonia, which dissolves the isamic acid and leaves the isatin.

Isamic acid crystallises in splendid, shining, rhombic laminæ, of the colour of red iodide of mercury. By spontaneous evaporation of the solution, ruby-coloured hexagonal tables are formed, with angles of about 110°. It dissolves sparingly in boiling water, forming a yellow solution, easily soluble in hot alcohol, somewhat less in ether.

Isamic acid dissolves with fine violet colour in hydrochloric acid. By boiling with dilute acids, it is converted into ammonia and isatin. Bromine attacks it violently, forming *indelibrome*, $C^{16}H^{5}Br^{4}N^{3}O^{3}$, a yellow substance insoluble in water.

Isamate of ammonium, $C^{16}H^{12}(NH^{4})N^{3}O^{4}$, crystallises in small needles or very acute microscopic rhombs. When somewhat strongly heated, it gives off water, and is converted into isamide. Its solution does not precipitate the salts of barium, calcium, or magnesium. It forms a yellow precipitate with *acetate of lead*, red with *mercuric chloride*, yellow with *nitrate of silver*.

Isamate of potassium may be boiled without decomposing.

Dichlorisamic acid, $C^{16}H^{11}Cl^{2}N^{3}O^{4}$.—Produced by adding hydrochloric acid to a solution of dichlorisamide in dilute potash, and crystallising the brick-red flocculent precipitate from alcohol. It forms bright red elongated hexagonal laminæ, derived from a rhombus of about 110°. It is more soluble than isamic acid in alcohol and ether, and forms yellow solutions. It is decomposed by distillation. Strong acids dissolve it, with violet colour, at ordinary temperatures; but at the boiling heat, they convert it into ammonia and chlorisatin.

Tetrachlorisamic acid, $C^{16}H^{9}Cl^{4}N^{3}O^{4}$.—Tetrachlorisamide is converted by boiling alcohol into tetrachlorisamate of ammonium; and on adding nitrate of silver to this salt, a flocculent precipitate is formed containing $C^{16}H^{8}AgCl^{4}N^{3}O^{4}$.

ISAMIDE. $C^{16}H^{14}N^{4}O^{3}$. *Amasatin.* (Laurent, Ann. Ch. Phys. [3] iii. 488.) Produced by heating isamate of ammonium till water is given off, and washing the residue with water. It is pulverulent, of a fine yellow colour, tasteless, inodorous, insoluble in water, nearly insoluble in ether, very sparingly soluble in alcohol, moderately soluble in boiling alcohol containing ammonia. Potash dissolves it with yellow colour, with elimination of ammonia; the solution contains isatin.

ISATAN. $C^{16}H^{12}N^{2}O^{3}$? (Laurent, J. pr. Chem. xxviii. 346.)—This body is sometimes produced when disulphisatyde is boiled with acid sulphite of ammonium, as a white precipitate, which dissolves when boiled with a large quantity of alcohol, and is deposited on cooling in crystals, which appear under the microscope, either as well-defined rectangles, or as pointed ovals, according to the side on which they are viewed. The compound, heated till it melts, turns brownish red, and yields a mixture of isatin and indin:

$$\underset{\text{Isatan.}}{3C^{16}H^{12}N^{2}O^{3}} = \underset{\text{Isatin.}}{2C^{8}H^{5}NO^{2}} + \underset{\text{Indin.}}{2C^{16}H^{12}N^{2}O^{2}} + H^{2}O.$$

It is decomposed by boiling nitric acid, with formation of a violet powder, similar to nitrindin. With alcoholic potash it forms a yellow solution, from which water precipitates hydrindin, and hydrochloric acid throws down isatin mixed with a resinous substance.

The composition of isatan is equal to that of 2 at. indigo-blue + 1 at. water ($2C^{8}H^{5}NO + H^{2}O$), and to that of isatyde *minus* 1 at. oxygen ($C^{16}H^{12}N^{2}O^{4} - O$).

ISATIC ACID. $C^{8}H^{7}NO^{3}$. (Laurent, Ann. Ch. Phys. [3] iii. 371.)—The potassium-salt of this acid is produced by the action of caustic potash upon isatin. The acid itself is not easily obtained in the free state.

The solution of the potassium-salt mixed with hydrochloric acid, deposits, after a while, crystals of isatin, which in fact differs from isatic acid, only by the elements of water:

$$\underset{\text{Isatic acid.}}{C^{8}H^{7}NO^{3}} = \underset{\text{Isatin}}{C^{8}H^{5}NO^{2}} + H^{2}O.$$

The composition of the isatates is represented by the formula $C^{8}H^{6}MNO^{3}$. The ammonium-salt appears to be capable of existing only in solution; for on evaporation to

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nverted into isamate of ammonium (p. 404). The
ed by the action of baryta-water on isatin, crystal-
ntains $C^8H^6KNO^3$. Isatin dissolves in a cold strong
olet-red liquid, which changes to pale-yellow when
evaporating the solution, the salt is obtained in
precipitates chloride of barium if the solutions are
ate of lead, a yellow flocculent precipitate, which
t, $C^8H^6AgNO^3$, is soluble in water, and crystallises
tained as a precipitate on mixing the boiling and
ate of potassium and nitrate of silver.

is obtained as a potassium-salt by the action of

(Erdmann, J. pr. Chem. xix. 360.)—This acid
acid to a concentrated solution of its potassium-
substance, soluble in a larger quantity of water.
nean temperatures, it is converted into dibromi-

$Br^2NO^3.H^2O$, is prepared by dissolving dibromi-
aving the solution to itself for a while. It crystal-
s, less soluble in water and in alcohol than the
lic salts the same reactions as the dichlorisatate
omisatosulphite of potassium, $C^8H^4KBr^2NO^3.2SO^2$.

. (Erdmann, Ann. Ch. Pharm. xxxiii. 129.—
78.)—This acid is not known in the free state, but
ed.

$KClNO^3$, is obtained by mixing warm, moderately
ash and chlorisatin. The salt separates on cooling
stallisation from alcohol. It crystallises in shining
light yellow colour, soluble in water and alcohol,
chloric acid added to its solution throws down

re obtained by double decomposition. The *barium-*
ure of the hot solutions of chlorisatate of potassium
pale yellow needles containing $C^{16}H^{10}Ba''Cl^2N^2O^8$.
rilliant laminæ containing $C^{16}H^{10}Ba''Cl^2N^2O^8.3H^2O$.
water between 150° and 160°. The *bismuth-salt*
The *calcium-salt* resembles the barium-salt. The
ic salt, when first precipitated, is bulky, and of
nges after a while to a heavy granular powder of a
a brown-red precipitate obtained by adding chlo-
The *lead-salt*, $C^{16}H^{10}Pb''Cl^2N^2O^8.2H^2O$, is produced
ecipitate, which, in a few minutes, especially if
a splendid scarlet colour, almost as bright as that
roscope, the yellow precipitate appears pulverulent,
but the red flocks present the appearance of den-
contain 1 at. water, which they give off at 160°.
lts appear to be soluble. The *mercury-salts* are
is a yellowish crystalline powder. The *silver-salt*,
cipitate, which dissolves in boiling water and crys-
d in tufts, or in dendritic vegetations of yellowish
ecipitate.

O^3. (Erdmann, Laurent, *loc. cit.*)—This acid
on of its potassium-salt, on addition of a mineral
pitate, which, however, cannot be obtained pure;
mean temperature, it separates into dichlorisatin
forming a light yellow solution, which becomes
satin.

$H^4KCl^2NO^3.H^2O$.—Dichlorisatin dissolves in cold
solution which becomes colourless when heated,
um-salt in shining yellow laminæ, which may be
cohol. They contain 1 at. water (= 5 per cent.),
below 130°. When crystallised from absolute
only half of that quantity of water. It is decom-
sion.

$O^6.2H^2O$, forms shining golden-yellow needles.—
pitate, which soon becomes greenish yellow and alter-

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nately crimson, these changes of colour arising from the crystallisation of the salt within the liquid. The *lead-salt* is a yellow precipitate. The *silver-salt* is a light yellow precipitate, which dissolves in a large quantity of boiling water, and crystallises on cooling in transparent yellowish needles, grouped in tufts. When heated in contact with the air, it melts to a brown mass, and yields a sublimate of dichlorisatin.

ISATILIM. $C^{24}H^{16}N^4O^5 = 3$ at. isatin + $NH^3 - H^2O$.—A substance stated by Laurent (J. pr. Chem. xxxv. 121) to be sometimes obtained when dry ammonia-gas is passed over isatin moistened with alcohol. Yellow non-crystalline flocks easily decomposed by potash. Its composition is rather doubtful.

ISATIMIDE. $C^{24}H^{17}N^5O^4$. (Laurent, *loc. cit.*)—Obtained by passing dry ammonia-gas over isatin moistened with alcohol, either ordinary or absolute. When absolute alcohol is used, *imesatin* (p. 246) first crystallises out in prisms with square or rectangular base; and the solution decanted therefrom deposits isatimide in the form of a yellow, shining, crystalline powder. It is insoluble in water, scarcely soluble in boiling alcohol or in ether, but dissolves easily in boiling alcohol, containing ammonia. Potash dissolves it with yellow colour and evolution of ammonia; the liquid contains isatin.

ISATIN. $C^8H^5NO^2$. (Laurent, Ann. Ch. Phys. [3] iii. 371.—Erdmann, J. pr. Chem. xxiv. 11.—A. W. Hofmann, Ann. Ch. Pharm. liii. 11.—Gm. xii. 51.—Gerh. iii. 534.)—This body, which was discovered simultaneously by Laurent and by Erdmann, in 1841, is produced by the action of nitric or chromic acid upon indigo:

$$\underset{\text{Indigo.}}{C^8H^5NO} + O = \underset{\text{Isatin.}}{C^8H^5NO^2}.$$

Preparation.—1 kilogramme of finely powdered, good commercial indigo is stirred up in a large dish to a thin paste with water; it is then placed over a moderate fire, and commercial nitric acid is gradually added (which causes a violent effervescence, without evolution of nitrous acid), until the blue colour has disappeared, for which, from 600 to 700 grms. of nitric acid are necessary. The solution is boiled with several quarts of water, and filtered at the boiling heat, as rapidly as possible; after 12 hours, the isatin separates in reddish crystalline nodules. The mother-liquor is boiled with the undissolved residue and filtered, the operation being two or three times repeated: the last mother-liquor still yields isatin on evaporation. The crystals are moistened with water containing a little ammonia, in order to remove a resinous matter; they are then washed with cold water, and finally recrystallised several times from boiling alcohol (100 pts. of indigo yield 18 pts. of isatin) (Laurent). When an excess of nitric acid is employed, nitrosalicylic acid is formed. After each addition of nitric acid, it is necessary to wait until the effervescence is over. If no effervescence takes place, in consequence of the indigo being mixed with too much water, and if the boiling is continued, whilst more and more nitric acid is added, a violent reaction suddenly ensues when the solution has reached a certain concentration, the mass overflowing the vessel even when it is very capacious: the residue generally contains nitrosalicylic acid (Hofmann).—2. Indigo is heated with chromic acid, properly diluted, until the whole nearly boils, when it is filtered hot; isatin then crystallises out on cooling, and is purified by repeated recrystallisation from water, and lastly from alcohol. If the chromic acid is so concentrated that it causes an evolution of carbonic anhydride, the solution deposits little or no isatin on cooling, but a small quantity by spontaneous evaporation or in vacuo; on evaporating the solution by heat, only sesquioxide of chromium and a brown powder separate (Erdmann). Laurent drops a dilute aqueous solution of chromic acid upon powdered indigo, and warms the mixture, the addition of chromic acid being discontinued as soon as the blue colour has disappeared, and the process continued as in (1). In order to purify crude isatin, which still contains resin, Hofmann dissolves it in potash, and carefully adds hydrochloric acid to the solution, as long as it forms a black or brown precipitate; when a portion on filtering is of a pure yellow colour, and gives a highly red precipitate with hydrochloric acid, the whole solution is filtered off, decomposed with hydrochloric acid, and the precipitate washed with a little water.

Properties.—Isatin crystallises in large, transparent, brownish-red prisms, or in smaller yellowish-red prisms, belonging to the trimetric system; the crystals are very brilliant, especially when obtained from an alcoholic solution. They exhibit the combination $\infty P . \infty\breve{P}\infty . \breve{P}\infty$; the faces $\infty\breve{P}\infty$ greatly predominating. Inclination of the faces $\infty P : \infty P = 133° 50'$ to $133° 55'$; $\breve{P}\infty : \breve{P}\infty = 127° 15'$ to $127° 30'$ (G. Rose, J. pr. Chem. xxiv. 11). Isatin is inodorous, and has a bitter taste. It melts when heated, and solidifies on cooling in a crystalline mass of needles; when heated above its melting point in contact with the air, the greater part volatilises, without decomposition, in yellow and very irritating vapours. It dissolves sparingly in cold, more freely in boiling *water*, forming a solution of a dark-reddish yellow colour. *Nitric*

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gentle heat, and deposits it unchanged on cooling.
easily in *ether*.
d in a retort leaves a large residue of charcoal
hrown upon glowing charcoal, it diffuses the same
upon platinum-foil, it burns with a brilliant flame,
ultly combustible charcoal.—2. When isatin is sus-
t of *chlorine* is passed through the solution, it is
lorisatin is formed, even if the solution is exposed
30° with *chloride of benzoyl*, yields a brown substance
l-isatin, $C^8H^4(C^7H^5O)NO^2$.—4. Moderately warm
decomposition, but on boiling, a violent action takes
itrous fumes, oxalic acid being formed together with
e in ammonia; no picric acid is formed.—5. Isatin
id, dissolves with brownish-red colour; a strong
on treating the solution with water and alcohol, a
ich has not been further investigated.—6. Isatin
undergoing decomposition, and imparts to it a
e, or immediately on boiling, the solution becomes
ate of potassium:

$$+ H^2O = C^8NH^7O^3.$$

by distillation, decomposition suddenly takes place,
passing over with the steam, and hydrogen being
n):

$$O = C^6H^7N + 2K^2CO^3 + H^2.$$

of isatin, various products of decomposition, which
on of the ammonia and the solvent of the isatin;
always formed, each containing 1, 2, or 3 at. isatin,
water.—8. *Phenylamine* behaves with isatin in a
rous acid in presence of alkalis, isatin forms salts of
in *sulphite of ammonium*, with formation of isatyde.
passed through an alcoholic solution of isatin, di-

ite with acids, but rather itself plays the part of
drogen for an equivalent quantity of metal. Isatin
tash, forming a very dark violet-red liquid, probably
H^4KNO^2. On diluting with water and boiling, the
d the solution is then found to contain isatate of
m, $C^{16}H^8(N^2H^6Cu)''N^2O^4$, is obtained as a light blue
ical solution of isatin into an ammoniacal solution of
r, $C^8H^4AgNO^2$, is a wine-red crystalline precipitate,
er with an alcoholic solution of isatin. It gave by
er (calculated quantity 42·52). On adding nitrate of
dine containing a considerable quantity of ammonia,
formed, consisting of *isatite of argentammonium*,
nalysis 35·23 per cent. carbon, 2·66 hydrogen, and
carbon, 2·58 hydrogen, and 39·85 silver).

Chlorinated Derivatives of Isatin.

scovered by Erdmann, have the composition of isatin,
replaced by an equivalent quantity of bromine or
satin in form and properties, and when treated with
dric acid, or alkaline sulphites, yield the chlori-
of the bodies which are produced by the action of

Erdmann, J. pr. Chem. xix. 358.—Hofmann, Ann.
und is produced, together with dibromisatin, by the
The product is exhausted with boiling water, and the
, are purified by recrystallisation from alcohol, the
onsisting principally of bromisatin (Erdmann).
suspend isatin in water, and shake it up in sunshine
ually added till the liquid no longer becomes colour-
is then boiled with weak alcohol, freed from hydro-
water, and recrystallised from boiling alcohol.

ling in shining orange-coloured prisms. Caustic

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potash converts it, at mean temperatures, into bromisatate of potassium. Distilled with hydrate of potassium, it yields bromophenylamine.

Dibromisatin. $C^8H^3Br^2NO^2$. (Erdmann, *loc. cit.*—Hofmann, *loc. cit.*—Laurent, Ann. Ch. Phys. [3] iii. 380.)—This body remains in the alcoholic mother-liquors obtained in preparing bromisatin, by the first of the methods above described, and may be separated by crystallisation; but a better way of preparing it is to digest isatin or bromisatin with bromine in sunshine, as long as hydrobromic acid continues to escape. It is purified by crystallisation from alcohol, from which it separates in shining orange-coloured trimetric prisms. When distilled with hydrate of potassium, it yields dibromophenylamine.

Dibromisatite of potassium, $C^8H^2KBr^2NO^2$, is obtained by gently heating a solution of dibromisatin in absolute alcohol, and pouring into it a hot solution of alcoholic potash. It crystallises in black scales, blue by transmitted light.

Chlorisatin. $C^8H^4ClNO^2$. (Erdmann, Ann. Ch. Pharm. xxiii. 129.—Laurent, Ann. Ch. Phys. [3] iii. 478.—Hofmann, Ann. Ch. Pharm. liii. 12.)—Produced: 1. By passing chlorine into tepid water, in which isatin is suspended.—2. By the action of chlorine on pulverised indigo suspended in water. A large quantity of a reddish yellow substance is thereby produced, consisting of a mixture of chlorisatin and dichlorisatin, which may be separated by solution in boiling alcohol, the chlorisatin separating out first. It is purified by repeated crystallisation from alcohol.

Chlorisatin crystallises in orange-coloured prisms, isomorphous with isatin. Observed combination, $\infty P \cdot \infty \breve{P}\infty \cdot \breve{P}\infty$. Inclination of the faces, $\infty P : \infty P = 131°$; $\breve{P}\infty : \breve{P}\infty = 134° 12'$ (G. Rose). It is inodorous, but has a bitter taste. Its dust irritates the organs of respiration and provokes sneezing. It is insoluble in cold water, but dissolves readily in boiling water and in alcohol. The solutions impart a disagreeable odour to the skin. Heated in contact with the air, it melts to a brown liquid, and gives off yellow vapours having the odour of burning indigo. At a high temperature, it partly sublimes and is partly carbonised.

Chlorisatin behaves with reagents like isatin. It dissolves in strong *sulphuric acid*, and separates on addition of water. With *nitric acid* it yields a resinous substance, oxalic acid, and a small quantity of an azotised body, which crystallises in yellow grains. *Sulphydric acid gas* passed into an alcoholic solution of chlorisatin, forms a white precipitate which increases on addition of water. Erdmann calls this precipitate sulphochlorisatin; according to Gerhardt, it is perhaps chlorinated tetrasulphisatyde, $C^{16}H^{10}Cl^2N^2S^4$ (analysis, 41·7 C, 2·37 H, and 31·09 S; calculation, 44·7 C, 2·33 H, 29·83 S).

Caustic *potash* communicates a deeper colour to chlorisatin, converting it into chlorisatite of potassium; on heating the liquid, the colour disappears, and the liquid contains chlorisatate of potassium.

Chlorisatite of argentammonium, $C^8H^3(NH^3Ag)ClNO^3$, is a crystalline precipitate, of the colour of wine-lees, obtained by pouring an ammoniacal solution of nitrate of silver into an alcoholic solution of chlorisatin mixed with ammonia.

Dichlorisatin, $C^8H^3Cl^2NO^2$, is obtained from the alcoholic mother-liquors, which have yielded chlorisatin, and is purified by recrystallisation from alcohol. It crystallises in small shining reddish-yellow needles, or shortened laminæ, fusible, partly volatile when heated in a close vessel, soluble in water and in alcohol.

Aqueous *potash* acts upon it in the same manner as upon chlorisatin. When dichlorisatin is thrown upon solid potash moistened with absolute alcohol, a red solution is formed, which after a short time, solidifies in a violet-black magma composed of dichlorisatite of potassium, the solution of which forms with nitrate of silver a precipitate having the colour of wine-lees.

Chlorine does not act upon chlorisatin or dichlorisatin in presence of water, but when either of these bodies is dissolved in hot alcohol of 80 per cent., and chlorine gas is passed through the liquid until nothing is formed but products of the decomposition of alcohol, a brownish yellow viscid mass is deposited at the bottom of the vessel, containing shining laminæ of *perchloroquinone* (chloranil). Water extracts sal-ammoniac from this mass, and alcohol dissolves chloride of ethyl, pentachloropicric acid, and a resinous mass which forms the largest portion of the product. The supernatant yellow solution contains products of the action of chlorine upon alcohol, and yields by distillation, a residue corresponding to the resinous substance, but not containing perchloroquinone. (Erdmann, Hofmann.)

ISATOSULPHURIC ACIDS. (G. and A. Schlieper, Ann. Ch. Pharm. cxxi. 1.)—Sulphindigotic acid, treated with oxidising agents, such as nitric acid or chromic acid, yields a monobasic acid containing the elements of isatin and sulphuric anhydride, viz. $C^8H^5NO^2.SO^3$; and the salts of this acid, treated with alkalis, yield a dibasic acid, containing the elements of isatin and sulphuric acid, viz. $C^8H^5NO^2.SO^4H^2$.

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a superior sort of commercial indigo-carmine (p. 261) an equal quantity of water; 1 or 2 pts. of sulphuric l to boiling; and 1 pt. of pulverised acid chromate of ons as long as decoloration ensues. The solution is d mixed with nitrate of potassium (to facilitate the crystalline paste which separates is collected on a d mother-liquor is separated by displacement with quid, evaporated and cooled, yields a small additional The isatosulphate of potassium thus obtained, in avy, sandy powder, is contaminated with a resinous ely, and cannot be separated. The acid and its salts converting them into dibasic isatosulphates by the these into the monobasic isatosulphates with acids. ed as above is dissolved in hot baryta-water, which tely decolorised, and the excess of baryta is precipi- ate carrying down all the resinous impurities with w solution contains a mixture of dibasic isatosul- satosulphate of barium; and on precipitating the h sulphuric acid, an orange-yellow solution of the the salt may be separated by evaporation and crys- , the solution be saturated while hot, with a quan- ient to neutralise the potash, the liquid, which has ur, deposits bulky, bright red, shining crystalline f barium.

acid, $C^8H^5NSO^5.2H^2O = C^8H^5NO^2.SO^3.2H^2O$, may ecomposing the solution of the barium-salt with an id.

gly acid solution, solidifies, when evaporated to a dio-crystalline mass, drying up in vacuo over sul- alline mass, which does not alter on exposure to the easily gives up its water of crystallisation at 100°. an in water, and is insoluble in *ether* and in *benzene*. cid, separating even the stronger mineral acids from by strong *sulphuric* or *nitric acid*, even with the aid or a mixture of *hydrochloric acid* and *chlorate of* with formation of chloranil. The aqueous solution *hlorine*. The alcoholic solution treated with *am*- rn-red bodies, probably amidated compounds. The *cid*, but the reduction is effected by *zinc* and *hydro*- ion being thereby completely decolorised. *Sulphy- f ammonium*, likewise reduce the acid, yielding the lphuric acid (p. 266).

sulphuric acid.—*Mono-ammonic isatosulphate*, by decomposing any other salt of the acid with an ich the resulting salt is sparingly soluble; or by with excess of sal-ammoniac. The salt crystallises sily soluble in water.

$N^2S^2O^{10}.3H^2O$, is formed by precipitating a solution th the free acid. It is insoluble in alcohol, sparingly hot water, forming a light yellow solution.

$N^2S^2O^{10}.2H^2O$, is obtained by precipitation, and -yellow needles which dissolve somewhat slowly in rium-salt.

$SO^5.H^2O$, crystallises in small gold-yellow needles insoluble in alcohol, dissolves in about 20 pts. of er, whence it crystallises slowly. It is not altered c acid. It gives off all its water of crystallisation at d all the salts of monobasic isatosulphuric acid 100°.

$NSO^5.H^2O$, separates slowly on mixing a solution of ver, in hard, needle-shaped, honey-yellow crystals,

$SO^5.2H^2O$, is obtained by mixing a hot-saturated two or three times its volume of a concentrated crystallises, on leaving the liquid at rest, in deep red

lphuric acid, $C^8H^5M^2NSO^6 = C^8H^5NO^4.SO^4M^2$.

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These salts are formed, as already observed, by the action of alkalis on the monobasic isatosulphates. All alkalis produce the change provided they are added in excess; if an insufficient quantity of alkali be added, a deep red, or sometimes dirty violet colouring is produced, which, though transient, is sufficient to indicate the formation of an intermediate compound. The transformation is likewise effected by alkaline carbonates.

Dibasic isatosulphuric acid has not been isolated; when separated from the solution of either of its salts, it is converted in a short time at ordinary temperatures, immediately when heated, into the monobasic acid.

The *diammonic salt* is produced by boiling isatosulphuric acid for some time with excess of ammonia, or by decomposing the dibarytic salt with sulphate of ammonium. The solution dries up, in vacuo over oil of vitriol, to a yellow gummy mass exhibiting but slight traces of crystallisation.

The *dibarytic salt*, $C^8H^5Ba''NSO^6.3H^2O$, is obtained by dissolving the monobarytic salt in boiling baryta-water, and removing the excess of baryta with carbonic acid. The slightly coloured solution yields, by evaporation or cooling, shining, lemon-yellow silky needles, more soluble than the monobasic salt in water, but insoluble in alcohol.

The *diplumbic salt*. $C^8H^5Pb''NSO^6.\frac{3}{2}H^2O$, is obtained by mixing a concentrated solution of the yellow potassium-salt with an excess of a concentrated solution of acetate of lead; it crystallises in slender, shining, dark yellow needles, which dissolve readily in water.

The *dipotassic salt*, $C^8H^5K^2N^2SO^6.H^2O$, obtained by decomposing the barium-salt with neutral sulphate of potassium, crystallises slowly, by spontaneous evaporation, in hard, shining, transparent, wax-yellow prisms, which dissolve readily in water, and give off their water of crystallisation between 140° and 150°.

The *diargentic acid*, $C^8H^5Ag^2NSO^6.\frac{3}{2}H^2O$, separates on mixing a solution of the potassium-salt with excess of nitrate of silver, in concentric groups of bulky needles, which, after drying, form a light spongy pale yellow mass. It is sparingly soluble in water, and does not give off its water of crystallisation till heated above 100°.

ISATOSULPHITES. (Laurent, Rev. scient. x. 289.—Gm. xiii. 56.—Gerh. iii. 544.)—Sulphurous anhydride does not act upon isatin alone; but in presence of potash or ammonia, peculiar salts are produced, containing the elements of isatate of ammonium or potassium, together with sulphurous anhydride. The acid corresponding to these salts has not been isolated, being decomposed when the salts are treated with a stronger acid. The chlorinated and brominated isatins yield corresponding compounds under the influence of alkalis and sulphurous acid.

Isatosulphite of Ammonium, $C^8H^6(NH^4)NO^3.2SO^2$, is obtained by boiling isatin with acid sulphite of ammonium, and concentrating the liquid by evaporation. It then separates in small rhomboïdal tables of a pale yellow colour, sparingly soluble in cold, but very soluble in boiling water.

Isatosulphite of Potassium, $C^8H^6KNO^3.2SO^2$, is produced by passing sulphurous anhydride to saturation into a solution of isatin in potash, or into a solution of isatate of potassium, or by boiling powdered isatin with acid sulphite of potassium, till it is completely dissolved.

The salt is neutral, has a faint yellow colour, is moderately soluble in water, and crystallises therefrom in elongated laminæ possessing considerable lustre. It is moderately soluble in boiling alcohol, very little in cold alcohol. Its solutions are yellow. When heated it aquires an orange-red colour, swells up and gives off water, and at a higher temperature blackens, and gives off a red thick matter, which solidifies without crystallising.—Iodine decomposes it at the boiling heat, isatin being precipitated and sulphuric acid remaining in the liquid. Chlorine also forms sulphuric acid, but at the same time throws down chlorisatin or dichlorisatin, according to the duration of the action. Hydrochloric acid poured into a boiling solution of the salt eliminates sulphurous anhydride, with effervescence, and precipitates isatin.

The solution of the potassium-salt does not form any precipitate with chloride of barium, strontium, or calcium, or with acetate of copper; but with nitrate of silver and acetate of lead, it forms precipitates consisting of a metallic sulphite, together with isatin.

Dibromisatosulphite of Potassium, $C^8H^4Br^2KNO^3.2SO^2$, is a yellow precipitate, sparingly soluble in water.

Chlorisatosulphite of Potassium, $C^8H^5ClKNO^3.2SO^2$, is obtained by passing sulphurous anhydride into a solution of chlorisatate of potassium. The liquid yields by evaporation a straw-yellow, fibro-lamellar salt, sparingly soluble in cold water. Acids decompose it, with precipitation of chlorisatin and evolution of sulphurous anhydride.

Dichlorisatosulphite of Potassium, $C^8H^4Cl^2KNO^3.2SO^2$. Yellow needles obtained by boiling dichlorisatin with acid sulphite of potassium.

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ISATYDE. $C^{16}H^{12}N^2O^4 = (C^8H^5NO^2)^2.H^2$. (Laurent, Ann. Ch. Phys. [3] iii. 32.—Gm. xiii. 98.—Gerh. iii. 551.)—A substance produced by the action of reducing gents, such as nascent hydrogen, sulphydric acid, sulphide of ammonium, &c. on atin; *e.g.*:

$$\underset{\text{Isatin.}}{2C^8H^5NO^2} + H^2S = \underset{\text{Isatyde.}}{(C^8H^5NO^2)^2.H^2} + S.$$

bears to isatin the same relation that indigo-white bears to indigo-blue.

The best mode of preparing it is to mix powdered isatin in a flask with a large uantity of water and a little sulphuric acid, then add a piece of pure zinc-foil, and eat the liquid. As the isatin dissolves, it takes up the nascent hydrogen, and is con-rted into pulverulent isatyde, which may be washed with water, and then boiled with cohol to remove undecomposed isatin. Isatyde may likewise be obtained by dissolv-g isatin in hot alcohol, and adding a small quantity of sulphide of ammonium. The ixture left to itself for a week deposits laminated and prismatic crystals of isatyde, ixed with octahedral crystals of sulphur, which must be removed by digestion with sulphide of carbon.

Isatyde is white, with a slight greyish tint, tasteless, and inodorous, and appears to e insoluble in water. It dissolves in very small quantity, in alcohol and ether, at the oiling heat, and separates on cooling in microscopic scales, having the form of oblique isms with rectangular base.

Isatyde softens when heated, and then turns violet-brown (being perhaps converted to a mixture of indin and isatin); if the heat be increased till the body is half elted, it suffers further decomposition, yielding a substance which dissolves in alcohol d crystallises in brown-red needles by evaporation.

Boiling nitric acid decomposes isatyde, producing a violet powder which ultimately ssolves. Potash likewise decomposes it, forming isatate of potassium and indin-otassium, which ultimately changes to hydrindin-potassium and other products of nknown constitution (see p. 264).

Erdmann (J. pr. Chem. xxiv. 15) gives the name of *isatyde* to a substance which obtained by dissolving isatin in hot sulphide of ammonium. This substance gave analysis numbers agreeing approximately with the formula $C^{16}H^{12}N^2O^3$. It was hite, very slightly crystalline, scarcely soluble in water, but soluble in ammonia, with d colour gradually changing to yellow. Potash dissolved it with deep-red colour, dis-ppearing when the liquid was heated; the solution, on cooling, deposited a crystalline lt, and yielded yellow flocks with hydrochloric acid.

Chlorisatydes and **Bromisatydes.** (Erdmann, Ann. Ch. Pharm. xxxiii. 129. Laurent, Ann. Ch. Phys. [3] iii. 382.)—*Dichlorisatyde*, $C^{16}H^{10}Cl^2N^2O^4$, is pro-uced by the action of sulphide of ammonium on chlorisatin. It is white, crystallis-le, insoluble in cold water, sparingly soluble in hot water; moderately soluble in oiling alcohol, soluble also, apparently without alteration, in a hot solution of sulphide potassium. Heated to 180°, it is resolved into chlorisatin and chlorindin:

$$\underset{\text{Chlorisatyde.}}{2C^{16}H^{10}Cl^2N^2O^4} = \underset{\text{Chlorindin.}}{C^{16}H^8Cl^2N^2O^2} + \underset{\text{Chlorisatin.}}{2C^8H^4ClNO^2} + 2H^2O$$

Chlorisatyde is coloured red by *ammonia*, and partially dissolved. It dissolves in oiling aqueous *potash*, being converted into chlorisatate of potassium, which ystallises on cooling. The mother-liquor, treated with *hydrochloric acid*, yields a pious light-yellow precipitate, which is partially dissolved by boiling water, the inso-ble part consisting of chlorindin, and the dissolved portion of chlorisatydic acid, obably a product of the decomposition of chlorindin. This acid is deposited from e aqueous solution in the form of a lemon-yellow substance, which forms, with otash, a soluble salt having little tendency to crystallise. The solution gives, with lts of lead, copper and barium, yellow precipitates which redissolve in the liquid nen heated.

Tetrachlorisatyde, $C^{16}H^8Cl^4N^2O^2$.—Produced by the action of sulphide of mmonium on tetrachlorisatin. It resembles the preceding compound, and is decom-sed in like manner by heat into tetrachlorisatin and tetrachlorindin. It likewise haves in a similar manner when boiled with potash, yielding, among other products, obably by a secondary decomposition of dichlorindin, the potassium-salt of a peculiar id (*dichlorisatydic* acid) which, as the liquid cools, is deposited in yellow, shining minæ.

Tetrabromisatyde, $C^{16}H^8Br^4N^2O^2$, resembles tetrachlorisatyde, and is prepared a similar manner. It turns brown when heated, and is resolved into dibromisatin d dibromindin.

Sulphisatyde, $C^{16}H^{12}N^2O^2S$. *Sulphasathyde.* (Laurent, Ann. Ch. Phys. [3]

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iii. 463).—Obtained by adding alcoholic potash drop by drop to an alcoholic sol of disulphisatyde:

$$\underset{\text{Disulphisatyde.}}{C^{16}H^{12}N^2O^2S^2} + KHO = \underset{\text{Sulphisatyde.}}{C^{16}H^{12}N^2O^2S} + KHS.$$

The liquid turns red, and after a few seconds deposits a white crystalline preci of sulphisatyde, which must be washed with boiling alcohol and dried. It gen has a faint rose tint, due to the presence of a small quantity of iodine.

Sulphisatyde when pure is a white, crystalline, inodorous, and tasteless powd crystallises from hot alcohol in microscopic rectangular scales. It is insoluble in Boiling *alcohol* dissolves only traces, which separate out on cooling in small cryst scales. It is not more soluble in *ether* than in alcohol.

Sulphisatyde, when *heated*, melts, turns red, swells up, and decomposes, while phuretted hydrogen is evolved, and a rose-coloured oil distils over, together wit vapour of a substance which crystallises in needles; finally, there remains a residue of charcoal. It is converted by *nitric acid* into a violet powder, in all probability, is nitrindin; the solution contains sulphuric acid. It is decom by cold *potash* with formation of various products, among which is indin; the so evolves sulphuretted hydrogen on the addition of hydrochloric acid, and gives cipitate consisting of sulphur and a little reddish matter. On treating sulphis with warm potash, hydrindin is formed.

Disulphisatyde. $C^{16}H^{12}N^2O^2S^2$. *Sulphésathyde.* (Erdmann, J. p. Chem. 16.—Laurent, Ann. Chim. Phys. [3] iii. 463.)—Produced by the action of sulph acid upon isatin.

The decomposition takes place in two stages, sulphur being first deposited isatyde produced, and this compound being afterwards converted into disulph with formation of water:

$$\underset{\text{Isatin.}}{2C^8H^5NO^2} + H^2S = \underset{\text{Isatyde.}}{C^{16}H^{12}N^2O^4} + S.$$

and

$$\underset{\text{Isatyde.}}{C^{16}H^{12}N^2O^4} + 2H^2S = \underset{\text{Disulphisatyde.}}{C^{16}H^{12}N^2O^2S^2} + 2H^2O.$$

Preparation.—When sulphydric acid gas is passed through a boiling concent alcoholic solution of isatin, the liquid becomes pale yellow, and forms a cryst deposit, which increases on cooling, and consists of microscopic sulphur-crystal scales (isatyde). The solution is left to itself for a week, that the greater part sulphur may crystallise out; it is then poured off and mixed with a little wate the resulting precipitate is removed, as it contains sulphur; it is then shaken up more water, which precipitates the disulphisatyde as a brownish grey resinou stance. (Laurent.)

Disulphisatyde, when dried, is a yellowish grey, inodorous, and tasteless po It does not crystallise from its alcoholic or ethereal solution, either on cooling spontaneous evaporation (Laurent). On drying at 110° it always becomes blu brick-red; if the solution is exposed to the air for some time before the additi water, the precipitate is brownish-red. (Erdmann.)

Disulphisatyde swells up strongly when heated in a glass tube, and melts, with tion of sulphydric acid; at the same time a brown oil and a needle-shaped subl are formed, and there remains a bulky residue of charcoal. When boiled with *nitric acid*, it puffs up, evolves pernitric oxide, and dissolves; water precipitates flakes from the solution. In boiling nitric acid diluted with its own bulk of wa puffs up and gives off nitrous fumes. If the reddish-brown swollen mass is t after a few minutes, with alcohol, the latter takes up a reddish substance, wh insoluble in water, but soluble in potash, from which it is precipitated by acids. portion insoluble in alcohol dissolves in potash, and on neutralising the solution an acid, a white precipitate, insoluble in water, is formed, consisting of micro needles. The liquid obtained by the action of nitric acid contains sulphuric aci no oxalic acid. *Bromine* acts violently upon disulphisatyde, with evolution of br of sulphur and hydrobromic acid, and forms a yellow mass containing bromind orange-yellow crystalline mass, and a little resin. Disulphisatyde dissolves in *sulphuric acid*, with the aid of a gentle heat; the red solution is not precipitat water; potash colours it green, but does not precipitate it. On treating disulphis with *potash*, sulphisatyde and various other products (amongst others, indin formed, which, however, cannot be produced at will. (According to Erdmann solution deposits a crystalline salt.) *Ammonia* behaves in a similar manner. *acid sulphite of ammonium*, at mean temperature, disulphisatyde produces v compounds, among which is found the ammoninm-salt of a peculiar acid, sulphisatanous acid. This salt is crystallisable, soluble in water and alcoho

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dichloride of platinum, a yellow precipitate, which, acid, yields the free acid.

phisatyde is treated with acid sulphite of ammonium rally deposited a mixture of indin with a white sul- ned; sometimes, however, a different reaction takes of *isatan* (p. 404).

See TITANATES.

$^2SO^4 = C^2H^4.SO^4H^2$. (Gm. viii. 428.—Gerh. ii. 234.)
h ethyl-sulphuric (sulphovinic) acid, and may be re-
d, $\left.\begin{matrix}(C^2H^4)''\\(SO)''\\H^2\end{matrix}\right\}O^2$, was discovered by Magnus in 1833
as been further examined by Liebig, Regnault, olbe (Ann. Ch. Pharm. cxii. 241), and Carius (*ibid.*
By the ebullition of ethionic acid (ii. 523).—2. By lphuric acid, or of sulphuric anhydride, on alcohol or idues of the preparation of ether.—3. By the action H^7NSO^3, which may be regarded as the amic acid of rine in dilute nitric acid, treated with nitrite of potas- e of potassium. (W. Gibbs, Sill. Am. J. [2] xxv. 30.)
ulphuric anhydride is passed into absolute alcohol alt; and the resulting yellowish oily liquid is mixed and then saturated with carbonate of barium. The te of barium; if the water were added gradually, and te of barium would be produced, but no isethionate.— is passed for some time into anhydrous ether; water e excess of ether containing heavy oil of wine; and ion; it then gives off, first ether, then alcohol, and ulphuric and isethionic acids, which may be separated barium.

barium-salt is cautiously decomposed with the exact ired, and the filtrate is evaporated, first by gentle l of vitriol.

ly acid liquid, which decomposes acetates and common tion a heat of 150°, but blackens at higher tempera-

O^4, are obtained by decomposing the barium-salt with phates. They are soluble and crystallisable, and are phates, with which they are isomeric, by their much ustaining, without alteration, a temperature of 200°. with caustic potash, hydrogen is evolved, and there xalate, sulphate, and sulphite, the proportion of these of heat which has been applied. Isethionate of potas-

e of phosphorus, yields $C^2H^4SO^2Cl^2$, or $\left.\begin{matrix}(C^2H^4)''\\(SO)''\end{matrix}\right\}O\ Cl^2$,
es with ammonia, yields taurine (Kolbe):

$H^3 + H^2O = C^2H^7NSO^3 + 2HCl$.

$H^3(NH^4)SO^4$, forms well-defined octahedrons, which vacuum, and do not lose weight at 120°.

, crystallises in transparent six-sided plates, which oss of weight. They melt at 320°, and decompose at ng, swelling up to more than 100 times its original f very pungent odour.

$2H^2O$, forms pale-green right prisms with rhombic es resting upon the acute edges. At 140° it turns water of crystallisation.

, forms rhomboidal prisms which are unalterable in position a heat of 300°. It melts between 300° and n cooling, solidifies into a fibrous mass having the diminished in weight. The salt crystallises readily

A compound isomeric with biuret (i. 600), produced rom-acetyl-carbamide:

$+ NH^3 = \underset{\text{Isobiuret.}}{C^2H^5N^3O^2} + \underset{\text{Bromo-form.}}{CHBr^3}$

It dissolves sparingly in cold, easily in hot water, and crystallises from the solution in long needles containing $C^2H^5N^3O^2.2H^2O$, and melting at 185°, whereas biuret forms indistinct crystalline aggregations, and melts at 177°. In all other respects, the two substances resemble each other exactly. (A. Baeyer, Ann. Ch. Pharm. cxxx. 154.)

ISOBROMOMALEIC ACID. See MALEIC ACID.

ISOCAJPUTENE. See CAJPUTENE (i. 311).

ISOCETAMIDE. See the next article.

ISOCETIC ACID. $C^{15}H^{30}O^2$.—An acid discovered in 1854 by Bouis (Compt. rend. xxxix. 923). It is produced by saponifying the oil of *Jatropha Curcas* (huile de médicinier), the quantity obtained being 18 or 20 per cent. of the weight of the oil. After separation by pressure from oleic acid, and crystallisation from alcohol, it forms shining scales which melt at 55°, and solidify again at 53·5°. Its *silver-salt* is soluble in water, very soluble in alcohol, melts when heated, and burns easily without odour, leaving a residue of metallic silver.

Isocetate of Ethyl, $C^{15}H^{29}(C^2H^5)O^2$, prepared by the usual methods, is odourless, melts at the heat of the hand, and solidifies at 21°, remaining perfectly transparent, and assuming a crystalline structure.

Isocetamide, $C^{15}H^{31}NO$, is obtained by heating the oil above mentioned with ammonia in a sealed tube. It is white, nacreous, melts at 67°, and is not attacked by strong potash.

ISOCYANURIC ACID. Syn. with FULMINURIC ACID.

ISODIBROMOSUCCINIC ACID. See SUCCINIC ACID.

ISODIGLYCOL-ETHYLENIC ACID. $C^6H^{10}O^6$. (Barth and Hlasiwetz, Ann. Ch. Pharm. cxxii. 96).—An acid isomeric with diglycol-ethylenic acid (ii. 914), produced by treating milk-sugar with bromine and the product with oxide of silver. A bromine-compound of milk-sugar, $C^6H^{10}O^5Br^2$, (not isolated) appears to be first formed; and this when treated with moist oxide of silver yields bromide of silver, and the acid, $C^6H^{10}O^6$.

The acid is prepared by heating 30 grms. milk-sugar (1 at. = $C^6H^{10}O^5$) with 60 grms. bromine and half a litre of water, to 100° in strong well-closed bottles. The somewhat dilute yellowish solution is neutralised with moist oxide of silver (or oxide of lead); and the filtered solution is decomposed by sulphydric acid, evaporated at a gentle heat, mixed with alcohol to remove a little lime, freed from alcohol by distillation, and saturated, while still hot, with carbonate of cadmium. The slightly acid solution, decolorised with animal charcoal, yields the cadmium-salt in groups of granular crystals. To obtain the free acid, the cadmium-salt is rubbed up to a thin paste with water, and decomposed while hot by sulphydric acid, and the filtrate is evaporated to a syrup, which gradually dries up to a soft, hygroscopic, crystalline mass.—This acid may also be obtained, without the formation of the intermediate bromine-compound, by treating milk-sugar with half the preceding quantity of bromine, neutralising the solution with carbonate of sodium, and boiling.

An acid, agreeing with the preceding in every respect excepting the amount of its rotatory power, is obtained in like manner from gum-arabic. With starch only, a small quantity of an uncrystallisable acid mass is obtained. Mannite, cane-sugar and glucose, treated with bromine and water, form hydrobromic acid, which then gives rise to the formation of humus-like products.

Isodiglycol-ethylenic acid dried over oil of vitriol contains 13·9 per cent. water, agreeing nearly with the formula, $2C^6H^{10}O^6.3H^2O$. It has a strong acid reaction, melts below 100°, and burns on platinum-foil, giving off the odour of burnt sugar. It dissolves in alcohol and is precipitated from the solution in flocks by ether. The aqueous solution is not precipitated by neutral or basic acetate of lead, mercuric nitrate, caustic baryta, or lime-water, but forms a white precipitate with ammoniacal sugar of lead. The ammonium-salt reduces an alkaline cupric solution, and forms a speculum when heated with nitrate of silver. The acid possesses optical rotatory power.

Isodiglycol-ethylenate of ammonium, $C^6H^9(NH^4)O^6.H^2O$, crystallises in large, transparent, glassy crystals of the monoclinic system. It dissolves in water, is nearly insoluble in alcohol, and gives off all its water at 120°.

The *cadmium-salt* crystallises from a hot-saturated solution in granular aggregates of monoclinic needles containing $C^{12}H^{18}Cd''O^{12}.3H^2O$; from dilute solutions, or from the mother-liquor by slow evaporation, in well-developed monoclinic crystals, mostly united in tufts. Both these hydrates, especially the former, are sparingly soluble in water, and both retain all their water of crystallisation till heated to 150°.

The *calcium-salt*, $C^{12}H^{18}Ca''O^{12}.7H^2O$, crystallises in crusts, or from more dilute solutions in large shining plates; it gives off 4 at. water at 100°, and the rest at 140°. There is also a calcium-salt containing only half as much water as the preceding.

The *barium-* and *strontium-salts* are gummy.

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The *copper-salt* is soluble and amorphous.

A *lead-salt* having approximately the composition, $C^{12}H^{16}Pb''O^{12}.4Pb''O.H^2O$, is obtained as a white precipitate on treating the solution of the acid with neutral acetate of lead and ammonia.

The *potassium-salt* forms a viscid uncrystallisable mass, easily soluble in water, and precipitated by alcohol.

The *silver-salt* is a gelatinous, easily decomposible precipitate, formed only in concentrated solutions.

The *sodium-salt* forms tufts of prisms, which in the air-dried state contain $C^6H^7NaO^6.2H^2O$, and give off half their water at 100°.

ISOMERISM. This term is derived from *ἴσος* equal, and *μέρος* part, and its employment by chemists is an expression of the fact that very different chemical compounds have sometimes identically the same ultimate composition.

Two or more different bodies which are composed of the same elements, and of the same proportions of those elements (*i.e.* which have the same percentage composition) are said to be isomeric.

Isomerism is sometimes used in a narrower sense, being made to signify equality of molecular weight, as well as identity in percentage composition. When the compounds have the same percentage composition but different molecular weights, the term polymeric is employed. Thus there are the terms *Isomeric* (in its wide sense), signifying that the different bodies have the same percentage composition; *Polymeric*, signifying that these different bodies have the same percentage composition, but different molecular weights; *Isomeric* (in its restricted sense), sometimes called *Metameric*, that the bodies have the same percentage composition and likewise the same molecular weight.

As might naturally be expected, cases of isomerism abound in organic chemistry, where an enormous number of compounds result from the combination of very few elements. The following organic substances may be cited by way of illustrating the employment of the term isomeric and its congeners.

Butyric acid	$\left.\begin{matrix}C^4H^7O\\H\end{matrix}\right\}O = C^4H^8O^2$
Acetic ether	$\left.\begin{matrix}C^2H^3O\\C^2H^5\end{matrix}\right\}O = C^4H^8O^2$
Aldehyde	$\left.\begin{matrix}C^2H^3\\H\end{matrix}\right\}O = C^2H^4O$
Oxide of ethylene	$(C^2H^4)''O = C^2H^4O$

These four bodies are quite different, and have the same percentage composition, viz.:

Carbon	54·55
Hydrogen	9·09
Oxygen	36·36
	100·00

They are *Isomeric*, or *Isomers*, using the term in its widest sense.

Again, butyric acid and aldehyde have different molecular weights:—

Butyric acid	$C^4H^8O^2 = 88$
Aldehyde	$C^2H^4O = 44$

Butyric acid and aldehyde are therefore *Polymeric*.

Similarly acetic ether and aldehyde are *Polymeric*, or acetic ether and oxide of ethylene are *Polymeric*, or butyric acid and oxide of ethylene are *Polymeric*.

Again, butyric acid and acetic ether have the same molecular weights, viz.:

Butyric acid	$C^4H^8O^2 = 88$
Acetic ether	$C^4H^8O^2 = 88$

They are therefore *Isomeric* (in the restricted sense) or *Metameric*. Aldehyde and oxide of ethylene are also metameric bodies.

Closely related to the term isomerism is the term allotropy. Both of them have reference to the same substantial fact, viz. that different substances have sometimes the same ultimate composition; but they differ in their manner of stating it. Isomeric and allotropic are in fact complementary terms, "isomeric" being employed to predicate identity of composition between different bodies, whilst "allotropic" expresses difference between bodies of identical composition.

Such being the force of these words, there is a certain propriety in their usage; thus whilst it is correct to say, "Butyric acid and acetic ether are *isomeric*," it should be "There are *allotropic* bodies of the formula, C^6H^7N." The same reason which enjoins the use of "allotropic" in this case, prescribes it in the instance of single elements; thus, for example, we read of "allotropic kinds of sulphur," but never of isomeric kinds.

It is worthy of remark that cases of isomerism occurring in inorganic chemistry, are

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usually described by employing the word allotropy or allotropic, whilst obtains in organic chemistry. This may be partly ascribed to there bei very wide difference—or else no difference at all—in the composition of inorganic substances; and hence the fact of identity or non-identity of being so easily ascertainable, it is implied in the form of expression, whils difference of properties alone needs to be made the subject of formal Among organic bodies, on the other hand, it continually happens that th of composition are quite decided, and yet so very minute as to tax the ut of chemical analysis for their recognition; and hence the superior dignit mere affirmation of identity of ultimate composition acquires in the org ment of the science.

The principal examples of allotropy or isomerism, *i.e.* of the coexistence ultimate composition with difference of properties, will now be considered.

Hydrocarbons.—1. The **olefines**, a numerous class having the gene C^nH^{2n}, form a very remarkable case of polymerism. Methylene, the lowest $n=1$, is wanting, and appears to be an impossible body; for many reactio it should be produced yield the higher terms instead. The olefines at pre are:

		Vapour-density.	B
Ethylene	C^2H^4	0·97	
Propylene	C^3H^6	1·45	
Butylene	C^4H^8	1·94	
Amylene	C^5H^{10}	2·42	
Hexylene	C^6H^{12}	2·91	
Heptylene	C^7H^{14}	3·39	
Octylene	C^8H^{16}	3·87	
Decatylene (paramylene)	$C^{10}H^{20}$	4·84	
Cetylene	$C^{16}H^{32}$	7·75	

By the destructive distillation of wax, Brodie obtained cerotene, for which $C^{27}H^{54}$ has been given; but there is in reality no reason whatever why C than any other out of a considerable number of formulæ, should be assigne

The percentage composition of the olefines is

Carbon	= 85·72
Hydrogen	= 14·28
	100·00

They present a certain general chemical character. All of them combin rine and bromine with great readiness. They differ in vapour-density, th beginning of the list increasing regularly in vapour-density by 0·4844. The gaseous at ordinary temperature and pressure; the third is a very volatile li at about 0° C.; the others on the list are liquids of which the boiling-point formula increases; and the very complex olefines which, being uncertain, ar list are usually believed to be solids. It will be observed that the increme point for the addition of CH^2 to the formula is large; between amylene an for instance, it is 34°. As the series is ascended, the increment become successively smaller and smaller.

The specific gravity of the different olefines in the liquid state seems to the formula increases.

There are certain well ascertained chemical differences between the olef the amount of olefine which will saturate a given quantity of chlorine, or differs according to the olefine taken, being proportional to the vapour-de molecular weights of the different olefines express their saturating capaci the vapour-densities are proportional to the molecular weights.

Each olefine may be prepared from a peculiar alcohol, and in general m to yield that peculiar alcohol by certain simple processes, *e. g.*:

Ethylic alcohol.				Ethylene.
C^2H^6O	–	H^2O	=	C^2H^4
Amylic alcohol.				**Amylene.**
$C^5H^{12}O$	–	H^2O	=	C^5H^{10}

and again:

Ethylene.				Ethylic alcohol.
C^2H^4	+	H^2O	=	C^2H^6O
Amylene.				**Amylic alcohol.**
C^5H^{10}	+	H^2O	=	$C^5H^{12}O$.

If the alcohol and the olefine standing in these relations to it be comp be seen that they resemble one another in the number of carbon-atoms conta molecules.

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ıve of the difference between the olefines is that their
of complexity, and that, in fact, different carbon-
Thus in ethylene we have the carbon radicle, C^2, and
ained from certain compounds containing the radicle
ntaining the radicle C^2. Again in amylene there is
ained from compounds of C^3, which it in turn may

ous example of polymerism, being at one and the
ous. Recent investigations render it probable that
icted sense (or metamerism) among the olefines. It
e body having the formula, C^6H^{12}, the hexylene de-
allotropic with that got from other sources (p. 155).
e distinct varieties of amylene.
neral formula, C^nH^{2n+2}, there is a wide field for me-
usly an impossibility.
commonly recognised as possessing this general
-radicles and the alcohol-hydrides.
icle is metameric with ethyl-hydride.

$$\left.\begin{matrix}CH^3\\CH^3\end{matrix}\right\} = C^2H^6$$

$$\left.\begin{matrix}C^2H^5\\H\end{matrix}\right\} = C^2H^6$$

es, the possibility of cases of metamerism becomes
6 in the formula, C^nH^{2n+2}, we have the following
by the expressions hydride and alcohol-radicle :

$$\left.\begin{matrix}H\\C^6H^{13}\end{matrix}\right\} = C^6H^{14}$$

$$\left.\begin{matrix}CH^3\\C^5H^{11}\end{matrix}\right\} = C^6H^{14}$$

$$\left.\begin{matrix}C^2H^5\\C^4H^9\end{matrix}\right\} = C^6H^{14}$$

$$\left.\begin{matrix}C^3H^7\\C^3H^7\end{matrix}\right\} = C^6H^{14}$$

believing that alcohol-radicles and alcohol-hydrides
embraced by the formula, C^nH^{2n+2}. Nothing that
n of, for instance, the following additional allotropic
H^{14}.

$$\left\{\begin{matrix}C^3H^7\\C^2H^5\\H\\H\end{matrix}\right. ; \quad C\left\{\begin{matrix}C^3H^7\\CH^3\\CH^3\\H\end{matrix}\right. ; \quad C\left\{\begin{matrix}C^4H^9\\CH^3\\H\\H\end{matrix}\right. ; \quad C\left\{\begin{matrix}C^5H^{11}\\H\\H\\H\end{matrix}\right.$$

es between isomers having the general formula
own. A difference in the action of dry chlorine
has been observed by Frankland, methyl yielding
ereas ethyl-hydride gives $C^2H^4Cl^2$ as a liquid.
d, who has experimented under different conditions,
s the composition, vapour-density, and boiling point
vever, obtained common alcohol from it, and whether
de of ethyl remains, for the present, undecided.
urs in petroleum, is a very volatile liquid, boiling
does not condense at $-18°$, under the ordinary

netameric. $\left.\begin{matrix}C^4H^9\\H\end{matrix}\right\} = \left\{\begin{matrix}C^2H^5\\C^2H^5\end{matrix}\right.$

annite by the action, first of hydriodic acid, and then
nsensible to the action of chlorine, even in the pre-
dride of hexyl occurring in petroleum, on the other
by that agent.
exyl compounds from which the hexyl-hydride of
ed, tend to split up on oxidation, lends some kind
rmula for the mannite-hydride is

$$C\left\{\begin{matrix}C^2H^5\\CH^3\\CH^3\\CH^3\end{matrix}\right.$$

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but much remains to be done before any very positive opinion can be formed of nature of the metamerism subsisting between this mannite-hydride and the commo hexyl-hydride.

3. Two compounds with the empirical formula CH, viz. benzene and acetylene, p sent a curious case of polymerism.

These compounds have a certain likeness, both being products of the action very elevated temperature, but in other respects they are very unlike.

Benzene, C^6H^6, is a liquid, and is related to benzoic acid and phenylamine. Acetyle C^2H^2, is a gas possessing the peculiar property of attacking certain metallic solutio such as ammoniacal solution of cuprous chloride, and is related to common alcohol.

4. A large number of volatile oils differing much in smell, taste, boiling-po action with reagents, and in other important particulars, have had the formula C^{10} assigned to them. To this class belong the different kinds of oil of turpentine, oil lemons, neutral oil of cloves, oil of elemi-resin, carvene, and some others. Respect these bodies, the remark may be made that we are, for the most part, quite ig rant of their true formula: for, in the almost entire absence of derivatives, the m analysis of such hydrocarbons by our present methods is totally inadequate to dist guish between a variety of non-isomeric formulæ, all equally probable.

Isomers containing Carbon, Hydrogen, and Oxygen.

Both metamerism and polymerism occur very abundantly among these compoun

(1.) The ethers of the organic acids afford room for endless metamerism, as will apparent on a little consideration.

Acetate of methyl, $\left.\begin{matrix}C^2H^3O\\CH^3\end{matrix}\right\}O$, is metameric with formate of ethyl, $\left.\begin{matrix}CHO\\C^2H^5\end{matrix}\right\}O$, and w propionic acid, $\left.\begin{matrix}C^3H^5O\\H\end{matrix}\right\}O$. It is obvious that if we subtract nCH² from the acid-for ing radicle and add nCH² to the alcohol-forming radicle, or *vice versâ*, we must ge metamer. Hence it follows that any ether of an organic acid must have many metame if its molecular weight be tolerably high. Here is an example:—

Valerate of amyl	$\left.\begin{matrix}C^5H^9O\\C^5H^{11}\end{matrix}\right\}O$	= $C^{10}H^{20}O^2$
Butyrate of hexyl . . .	$\left.\begin{matrix}C^4H^7O\\C^6H^{13}\end{matrix}\right\}O$	= $C^{10}H^{20}O^2$
Propionate of heptyl . . .	$\left.\begin{matrix}C^3H^5O\\C^7H^{15}\end{matrix}\right\}O$	= $C^{10}H^{20}O^2$
Acetate of octyl	$\left.\begin{matrix}C^2H^3O\\C^8H^{17}\end{matrix}\right\}O$	= $C^{10}H^{20}O^2$
Formate of nonyl . . .	$\left.\begin{matrix}CHO\\C^9H^{19}\end{matrix}\right\}O$	= $C^{10}H^{20}O^2$
Caproate of tetryl . . .	$\left.\begin{matrix}C^6H^{11}O\\C^4H^9\end{matrix}\right\}O$	= $C^{10}H^{20}O^2$
Œnanthate of trityl . . .	$\left.\begin{matrix}C^7H^{13}O\\C^3H^7\end{matrix}\right\}O$	= $C^{10}H^{20}O^2$
Caprylate of ethyl . . .	$\left.\begin{matrix}C^8H^{15}O\\C^2H^5\end{matrix}\right\}O$	= $C^{10}H^{20}O^2$
Pelargonate of methyl . .	$\left.\begin{matrix}C^9H^{17}O\\CH^3\end{matrix}\right\}O$	= $C^{10}H^{20}O^2$
Rutic acid	$\left.\begin{matrix}C^{10}H^{19}O\\H\end{matrix}\right\}O$	= $C^{10}H^{20}O^2$

Thus there are no fewer than nine metamers of valerate of amyl. The differen between metamers of this kind is very neatly defined by reactions, saponificati with potash yielding a different alcohol and a potassium-salt of a different acid in ea case. For example, valerate of amyl gives amyl-alcohol and valerate of potassiu whilst butyrate of hexyl gives hexyl-alcohol and butyrate of potassium.

This kind of metamerism is of course, not confined to the fatty-acid series: whenev there are homologues of the acids—no matter what the series to which the acid belon —such metamerism is possible. And of course the same remark applies to the alcoh the aromatic and the allylic series admitting of just the same kind of metamerism the vinic series.

(2.) Every alcohol in a series, except the lowest one, is metameric with one or mo ethers, thus:—

Common alcohol	$\left.\begin{matrix}C^2H^5\\H\end{matrix}\right\}O$	= C^2H^6O

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Methyl-ether . . . . . $\left.\begin{matrix}CH^3\\CH^3\end{matrix}\right\}O$ = C^2H^6O.

r up in the scale:—

Amyl-alcohol . . . . . $\left.\begin{matrix}C^5H^{11}\\H\end{matrix}\right\}O$ = $C^5H^{12}O$

Cetryl-methyl ether . . . . . $\left.\begin{matrix}C^{15}H^{31}\\CH^3\end{matrix}\right\}O$ = $C^{16}H^{34}O$

Trityl-ethyl ether . . . . . $\left.\begin{matrix}C^{19}H^{15}\\C^2H^5\end{matrix}\right\}O$ = $C^{21}H^{20}O$.

ction of iodide of phosphorus upon these different compounds enables us to dis- them immediately.

The aldehydes are metameric with ketones, with alcohols of the allylic series, ethers of the glycol series, thus:

Propylic aldehyde . . . . . $\left.\begin{matrix}C^3H^4O\\H\end{matrix}\right\}$ = C^4H^6O

Common acetone . . . . . $\left.\begin{matrix}C^3H^3O\\CH^3\end{matrix}\right\}$ = C^4H^6O

Allylic alcohol . . . . . $\left.\begin{matrix}C^3H^5\\H\end{matrix}\right\}O$ = C^3H^6O

Oxide of tritylene . . . . . $(C^3H^5)''O$ = $C^6H^{10}O$.

four compounds are very easily distinguished from one another: the first is idised to propionic acid; the second gives no propionic acid on oxidation, but ty acids instead; the third gives acrolein and acrylic acid; the fourth lactic

Ketones are metameric with other ketones and with aldehydes and compounds ic therewith.

metamerism with other ketones is very easy to understand. The rational formula tones consisting of an acid-forming radicle conjoined with an alcohol-forming t follows that transference of nCH^2, from one radicle to the other will yield bodies. Thus, for instance, we have isomers in

Ethyl-valeryl . . $\left.\begin{matrix}C^5H^9O\\CH^3\end{matrix}\right\}$ and Ethyl-butyryl . . $\left.\begin{matrix}C^4H^7O\\C^2H^5\end{matrix}\right\}$

nowledge of the ketones is very slight, but it is to be expected that these two ds would give different products on being oxidised.

meric Alcohols.—It has recently been discovered that there are at least two alcohols, the corresponding terms of which are metameric, well-marked differ- ving been recognised between compounds with the composition of hexylic and also between compounds with the composition of amylic alcohol. It is at ncertain what the nature of this metamerism is (see HEXYL-ALCOHOLS, p. 152), ems to affect the total constitution of the two sets of compounds.

e superficial kind of difference was noticed by Pasteur, some years ago, be- rieties of amylic alcohol. Ordinary fusel-oil was found by Pasteur to be made o liquids having the composition of amylic alcohol, but slightly different in es, the one being without action on polarised light, whilst the other turned the a polarised ray to the left. The derivatives of each of these varieties of lcohol possess the same action on polarised light as the alcohols themselves, sent some differences in solubility, &c., but on the whole they are marvellously Chemists are not agreed how these varieties are to be regarded, it being still n whether a mere difference in action upon polarised light points to any but the htest difference in constitution.

meric Acids.—There is some reason for believing that the fatty acids, when in the liquid state, have twice the molecular weight which their vapours have ated up to 300° and higher. Their great tendency to form double salts, and hat their vapours at low temperature—whether under great or small pressure— ouble density, point to this conclusion.

ting the double formula for the fatty acids, some very interesting cases of ism arise. Thus, propionic acid is metameric with butyr-acetic acid:—

Propionic acid . . . $\left.\begin{matrix}C^3H^5O\\C^3H^5O\\H^2\end{matrix}\right\}O^2$ = $C^6H^{12}O^4$,

Butyr-acetic acid . . . $\left.\begin{matrix}C^4H^7O\\C^2H^3O\\H^2\end{matrix}\right\}O^2$ = $C^6H^{12}O^4$,

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and, in like manner, each term of the series, except the end ones, is metameric with compound acid formed of the next below united with the next above. It is worth of remark, as a fact in the history of organic chemistry, that butyr-acetic acid wa mistaken for, and described as, propionic acid.

The anhydrides of the aromatic and fatty acids offer a systematic metamerism, *e.g.*

Aceto-valeryl anhydride . . $\left.\begin{matrix}C^2H^3O\\C^5H^9O\end{matrix}\right\}O = C^7H^{12}O^3$,

and

Propio-butyryl anhydride . $\left.\begin{matrix}C^3H^5O\\C^4H^7O\end{matrix}\right\}O = C^7H^{12}O^3$,

are metameric. In fact there is, among these anhydrides, just a repetition of the cas of the ethereal-salts of the organic acids; by making nCH^2 move from the one radicl to the other, endless metamerism arises.

No case of metamerism between two single fatty acids has yet been made out; bu in the aromatic series, there are such cases: thus there are two benzoic acids.

A very remarkable example of metamerism is afforded by the different varieties c tartaric acid and racemic acid. There is a tartaric acid which polarises to the righ (the commonest), another which polarises to the left; racemic acid, from which bot varieties of tartaric acid may be obtained; and, finally, a tartaric acid without an action upon polarised light. All these substances are metameric, having the formul

$$C^4H^6O^6.$$

Polyatomic Alcohols.—Mannite and melampyrin are metameric, both of them havin the formula

$$C^6H^{14}O^6.$$

The most striking difference between these bodies is to be found in their degrees c solubility in water—mannite being comparatively soluble, melampyrin comparativel insoluble. In reactions they are, so far as is known, very similar.

There seem to be many metamers both of grape-sugar and of cane-sugar, but littl is known with certainty respecting them.

Examples of polymerism are not by any means so numerous among the compound of carbon, hydrogen, and oxygen, as we have found the examples of metamerism to be There can be no polymers either of the vinic alcohols or vinic ethers.

The fatty acids, and the ethers of the fatty acids, are polymeric with more comple acids, or with compounds of the sugar-class; but even among them, there is nothin approaching to the endless metamerism which has been referred to.

Acetic acid offers one of the best examples of a fatty acid polymeric with severa substances:

$2(CH^2O) = C^2H^4O^2$, acetic acid,
$3(CH^2O) = C^3H^6O^3$, lactic acid,
$6(CH^2O) = C^6H^{12}O^6$, grape-sugar.

By doubling the formula of any aldehyde, we get the formula of a fatty acid, thus:

C^2H^4O, common aldehyde,
$C^4H^8O^2$, butyric acid.

By tripling the formula of an aldehyde, we get the formula of an acid of the lacti series, *e.g.*:

C^2H^4O, common aldehyde,
$C^6H^{12}O^3$, leucic acid.

Grape-sugar is polymeric with ethyl-carbonic acid: Grape-sugar = $C^6H^{12}O^6$; 2 mole cules of ethyl-carbonic acid = $2.\left.\begin{matrix}CO\\C^2H^5\\H\end{matrix}\right\}O^2 = 2C^3H^6O^3 = C^6H^{12}O^6$.

Isomers containing Carbon, Hydrogen, and Nitrogen.

(1.) *Metamerism among the compound ammonias.*

The following compound ammonias have the formula $C^6H^{15}N$:—

Hexylamine . . . . $\left.\begin{matrix}C^6H^{13}\\H\\H\end{matrix}\right\}N = C^6H^{15}N$

Amyl-methylamine . $\left.\begin{matrix}C^5H^{11}\\CH^3\\H\end{matrix}\right\}N = C^6H^{15}N$

Tetryl-ethylamine . . . $\left.\begin{matrix}C^4H^9\\C^2H^5\\H\end{matrix}\right\}N = C^6H^{15}N$

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mine . . $\left.\begin{matrix}C^6H^9\\CH^3\\CH^3\end{matrix}\right\}N = C^8H^{15}N$

. . . $\left.\begin{matrix}C^5H^7\\C^3H^7\\H\end{matrix}\right\}N = C^8H^{15}N$

ylamine . $\left.\begin{matrix}C^3H^7\\C^2H^5\\CH^3\end{matrix}\right\}N = C^8H^{15}N$

. . . $\left.\begin{matrix}C^2H^5\\C^2H^5\\C^2H^5\end{matrix}\right\}N = C^8H^{15}N.$

uishes the different compound ammonias from one h nitrous acid, they give up their different alcohol- For example, the first base on our list, hexylamine, exyl-alcohol; the second, amyl-alcohol and methyl- and ethyl-alcohol, &c.

iethylamine has six distinct metamers: but if, as is e of the three atoms of hydrogen in ammonia has a tamers of triethylamine will become very numerous

her we go—the higher the molecular weight of a base

ossible metamers. Thus tricetylamine, $\left.\begin{matrix}C^{16}H^{33}\\C^{16}H^{33}\\C^{16}H^{33}\end{matrix}\right\}N$, has

of which should give a different result with nitrous

netamerism, due to the presence of different alcohol- other kinds of metamerism among the compound

ll-known case of the bases parallel with phenylamine,

= C^8H^7N = Picoline
= C^7H^9N = Lutidine.
&c. &c.

metamerism in this case is that phenylamine is a deri- picoline is derived from a hydrocarbon C^6H^{10}.

amine = $(C^6H^5)'NH^2$
= $(C^6H^7)'''N$.

e of the difference in constitution between these two s is very striking:

61;
e, &c. on
oxidising

Picoline boils at 135°:
most pungent and bad smell:
very soluble in water:
specific gravity at 0° = 0·9613.

d much further.

meric with the foregoing has been discovered. The ies is β-lutidine, which is obtained by the destructive s less soluble in water than common lutidine, boils ell, &c.

f nitrogen to coalesce and form a group requiring either atives for its saturation. Three or even four atoms of the bases so resulting there must be almost infinite

ompounds of Carbon, Hydrogen, and Nitrogen.

ne are polymeric, the formula of the latter being three

N = Cyanide of ethyl.
$^5N^3$ = Cyanethine.

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The former is a liquid, the latter a solid possessing the properties of a weak base. It is probable that the rational formula of the latter is:

$$N^3\begin{cases}C^3H^{5'''}\\C^3H^{5'''}\\C^3H^{5'''}\end{cases}$$

It will be obvious that the existence of compound ammonias containing more than one atom of nitrogen in the molecule opens the door for much polymerism.

Isomers containing Carbon, Hydrogen, Nitrogen, and Oxygen.

The metamerism between cyanate of ammonium and urea, is one of the oldest known.

Cyanate of ammonium . . . . . $\begin{matrix}CN\\NH^4\end{matrix}\Big\}O = CH^4N^2O$

Urea . . . . . $\begin{matrix}CO''\\H^4\end{matrix}\Big\}N^2 = CH^4N^2O.$

Although cyanate of ammonium is transformed spontaneously into urea, yet there is a very great difference between the characters of the two compounds. One striking difference between a solution of a cyanate and a solution of urea is the comparative stability of the latter.

Glycocine and nitrite of ethyl are metameric:

Glycocine . . . . . $\begin{matrix}C^2H^2NH^2O\\H\end{matrix}\Big\}O = C^2H^5NO^2,$

Nitrite of Ethyl . . . . . $\begin{matrix}NO^2\\C^2H^5\end{matrix}\Big\} = C^2H^5NO^2,$

but are utterly different in properties. Glycocine (sugar of gelatin) is a crystalline solid. Nitrite of ethyl is a liquid.

Anthranilic acid	$C^7H^7NO^2$
Benzamic acid	$C^7H^5NH^2O^2$
Salicylamide	$C^7H^5NH^2OO$
Nitrotoluene	$C^7H^7NO^2$

are metameric.

Besides these, there are many more examples of metamerism among compounds of carbon, hydrogen, nitrogen, and oxygen, but we need not particularise them.

Polymerism also occurs in abundance. A very frequently cited example of this is afforded by

Cyanic acid	CHNO
Cyanuric acid	$C^3H^3N^3O^3$

Fulminic acid, $C^2H^2N^2O^2$, is also polymeric with the above, but it is only known in the form of its salts—not in the free state.

Organic Isomers containing various elements in addition to the so-called Organic Elements.

They are very abundant. A good example of metamerism between chlorinated compounds is afforded by dichloride of ethylene and chloride of monochlorethyl:

Dichloride of ethylene, $(C^2H^4)''Cl^2$,
boils at 85°;
specific gravity at 18° = 1·247;
with alcoholic solution of potash, gives $C^2H^3Cl + HCl$;
with sodium in presence of ether gives $C^2H^4 + 2NaCl$;

Chloride of monochlorethyl, C^2H^4ClCl;
boils at 64°;
specific gravity at 17° = 1·174;
with alcoholic solution of potash, hardly any reaction;
with potassium gives no reaction.

A very interesting case, from the extreme simplicity of the compounds, is to be found between the chlorine-derivative obtained by direct action of chlorine on marsh gas, and common chloride of methyl. Both of these compounds have the empirical molecular formula, CH^3Cl, and both are gaseous at ordinary temperatures and pressures, but they possess some unmistakable differences in properties.

There are corresponding brominated compounds—Bunsen obtained a gas from bromhydrate of cacodylic acid. The composition of the gas is the same as that of bromide of methyl, viz., CH^3Br; but whilst bromide of methyl is a liquid boiling at 13°, Bunsen's brominated gas does not liquefy below −17° C.

Many more cases of isomerism among these semi-organic and semi-inorganic compounds might be cited.

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Isomers among Inorganic Substances.

s before remarked, the instances of inorganic isomerism are usually called instances llotropy—isomeric substances and allotropic substances being nearly equivalent ex- sions.

he elementary substances themselves offer many examples of isomerism. Thus gen appears to be capable of existing in two allotropic states; in one condition it is wn as ordinary oxygen, in the other as ozone. Ozone and oxygen are isomeric ies. Formula for oxygen = O^2; formula for ozone = O^4(?) Experiment has wn that the molecular formula for ozone is higher than that for oxygen; but how h higher remains an open question.

ulphur, phosphorus, carbon, and many other elements present *somewhat* similar mples of allotropy or isomerism.

norganic compounds, such as the various forms of silicic acid, of sesquioxide of iron, esquioxide of chromium, of alumina, must be classed among substances affording mples of isomerism.

here seem to be two allotropic states of peroxide of nitrogen. The compound NO^2 deeply-coloured gas at 100°. The compound N^2O^4 is a liquid boiling a little w 30°. Its vapour-density is double that of the former body. Altogether, in- anic isomerism is a very wide, but as yet a very ill-explored field.

he explanation of the existence of isomerism will have become sufficiently clear n the course which has been followed in describing the different examples of it. is of consequence how the atoms of a compound are arranged as well as what kind atoms they are," and hence there may be very many totally different substances posed of the same ultimate atoms. This is in fact the whole philosophy of iso- ism.

J. A. W.

SOMORPHISM. (*Ἴσος*, equal, and *μορφή*, form.) Crystalline form affords, as is l known, one of the most valuable physical distinctions between different substances, much as each element, and each compound, crystallises for the most part in forms ch are reducible to one or two primary forms. Hauy, who first directed attention he importance of this character, laid it down as a general law, that every substance has a nary crystalline form peculiar to itself, and therefore that a difference in the primary ns of two crystals may always be taken as evidence of difference of composition. towards the end of the last, and the beginning of the present century, various ervations were made tending to disprove the generality of this law. The similarity orm between phosphate of calcium (apatite) and phosphate of lead (pyromorphite) s noticed by Werner. Leblanc in 1787, showed that a mixed solution of ferrous l cupric sulphates deposits crystals containing both copper and iron, always of the ne form, but with considerable variations in the proportions of the two metals; also t alum containing a considerable quantity of ferric oxide crystallises exactly in the ne form as pure alumino-potassic sulphate. Vauquelin, in 1797, showed that the ne form is exhibited by alum, when it contains a considerable quantity of ammonia place of potash. Berthier, in 1806, pointed out the great similarity in the form of c-spar, bitter spar, and spathic iron—a resemblance confirmed by the more exact asurements of Wollaston; and Gay-Lussac, in 1816, showed that a crystal of ash-alum immersed in a solution of ammonia-alum increases in bulk without eration of form. These and other isolated observations of similar import may be d to have prepared the way for the establishment, by Mitscherlich, of the general v of isomorphism, which affirms that *bodies having a similar chemical constitution ve also the same crystalline form, as determined by the measurement of their angles*, or, other words, that *analogous elements and groups of elements may replace one another composition without essential alteration of crystalline form.* Mitscherlich's first servations, presented to the Berlin Academy of Sciences in 1819, related to the iso- rphism of the phosphates and arsenates, and showed that the corresponding salts of osphoric and arsenic acids containing equal numbers of atoms of water, crystallise in same forms. Similar observations were subsequently made upon the sulphates, enates, manganates, and chromates; the protosalts of magnesium, zinc, cadmium, anganese, iron, nickel, cobalt, and copper, and the sesquisalts of iron, aluminium, romium, and manganese, the corresponding salts being supposed in all cases to contain ual numbers of atoms of water.

Bodies having apparently an exactly similar constitution are not necessarily iso- rphous, but are rather divisible into two or more groups, of which the respective embers are isomorphous; on the other hand, the possession of an equal number atoms is not essential to isomorphism, for two atoms of one element are not unfre- ently isomorphous with one atom of another element; and sometimes a molecular oup is isomorphous in its combinations with an elementary atom—NH^4 with K, for

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example. There are also numerous examples of bodies crystallising in the same forms, but without exhibiting any similarity of chemical constitution.

The corresponding angles of isomorphous bodies are not always precisely equal, but may differ from each other by one or two degrees. This discrepancy, however, is rendered unimportant by the circumstance, that the angles of different crystals of one and the same substance can present similar variations, under the influence of certain modifying causes.

It will of course be understood that the similarity of form in isomorphous bodies relates to the primary forms to which they are reducible; two crystals may be really isomorphous, and yet very different in external form, in consequence of being differently modified; thus calc-spar, bitter spar, and spathic iron have the same primary form; but each exhibits numerous modifications, some of which prevail chiefly in one, some in another, of these compounds.

The following table exhibits the most important and best established examples of isomorphism, arranged according to the crystallographic systems. Bodies crystallising in the same forms (*i. e.* reducible to the same primary form) are arranged in groups, numbered consecutively, without regard to the system to which the several forms belong; the subdivisions *a*, *b*, *c*, &c., include those also which correspond in atomic constitution.

Table I.

Monometric or *Regular System.*

Group 1. (Holohedral forms.)

a. Diamond,—Phosphorus,—Potassium,—Sodium,—Titanium,—Cadmium,—Lead,—Copper,—Silver,—Gold,—Platinum,—Palladium,—Iridium,—Tin (Frankenheim),—Zinc (Nicklès).

b. ZnS,—MnS,—PbS,—PbSe,—Ag^2S,—$NiS.2FeS$ (Scheerer),—MgO (periclase, according to Scacchi),—NiO (formed in a metallurgic process),—PbO,—CuO (tetrahedral),—UO.

c. KCl,—NaCl,—LiCl,—NH^4Cl,—AgCl,—CuCl,—KI,—NaI,—KBr,—NaBr,—KF,—NaF,—KCy.NaCy,—NH^4Cy (Gay-Lussac).

c'. ZnI^2,—CaF^2,—$KAgCy^2$,—$NiAS^2$ (arsenical nickel),—(Co; Ni)As^2 (cobalt-speiss).

d. $CoAs^3$ (tesseral pyrites, according to Wöhler and Scheerer).

e. Cu^2O,—Cu^2S (red copper and glance-copper).

f. As^2O^3,—Sb^2O^3,—Co^2S^3 (cobalt-pyrites).

g. $\left.\begin{matrix}\ddot{Mg}\\ \ddot{Al}^2\end{matrix}\right\}O^4$ (spinel),—$\left.\begin{matrix}(Mg;\ Fe)''\\ \ddot{Al}^2\end{matrix}\right\}O^4$ (pleonast),—$\left.\begin{matrix}\ddot{Mg}\\ \ddot{Fe}^2\end{matrix}\right\}O^4$ (chlorospinel,—$\left.\begin{matrix}\ddot{Zn}\\ \ddot{Al}^2\end{matrix}\right\}O^4$ (gahnite),—$\left.\begin{matrix}\ddot{Zn}\\ \ddot{Fe}^2\end{matrix}\right\}O^4$ (franklinite),—$\left.\begin{matrix}\dot{Fe}\\ \ddot{Fe}^2\end{matrix}\right\}O^4$ (magnetic iron ore),—$\left.\begin{matrix}\dot{Fe}\\ \ddot{Cr}^2\end{matrix}\right\}O^4$ (chrome iron ore, according to Abich).

h. BaN^2O^6,—SrN^2O^6,—PbN^2O^6. (Berzelius.)

i. $K^2\ddot{\ddot{P}}tCl^6$,—$K^2\ddot{\ddot{I}}rCl^6$,—$K^2\ddot{\ddot{O}}sCl^6$,—$(NH^4)^2\ddot{\ddot{P}}tCl^6$,—$(NH^4)^2\ddot{\ddot{I}}rCl^6$. (Berzelius.)

k. Alums: $(NH^4)\ddot{Al}(SO^4)^2.12H^2O$,—$(NH^4)\ddot{Cr}(SO^4)^2.12H^2O$,—$(NH^4)\ddot{Mn}(SO^4)^2.12H^2O$,—$(NH^4)\ddot{Fe}(SO^4)^2.12H^2O$,—$K\ddot{Al}(SO^4)^2.12H^2O$,—$K\ddot{Cr}(SO^4)^2.12H^2O$,—$K\ddot{Mn}(SO^4)^2.12H^2O$,—$K\ddot{Fe}(SO^4)^2.12H^2O$,—$NaAl(SO^4)^2.12H^2O$ (Mitscherlich),—$LiAl(SO^4)^2.12H^2O$ (Kralovansky),—$AgAl(SO^4)^2.12H^2O$ (Church), $TlAl(SO^4)^2.12H^2O$ (Crookes).

l. Garnets: $\left.\begin{matrix}\ddot{\ddot{Si}}^3\\ \ddot{Ca}\\ \ddot{Al}^2\end{matrix}\right\}O^{10}$,—$\left.\begin{matrix}\ddot{\ddot{Si}}^3\\ \ddot{Mg}\\ \ddot{Al}^2\end{matrix}\right\}O^{10}$,—$\left.\begin{matrix}\ddot{\ddot{Si}}^3\\ \ddot{Fe}\\ \ddot{Al}^2\end{matrix}\right\}O^{10}$,—$\left.\begin{matrix}\ddot{\ddot{Si}}^3\\ \ddot{Mn}\\ \ddot{Al}^2\end{matrix}\right\}O^{10}$,—$\left.\begin{matrix}\ddot{\ddot{Si}}^3\\ \ddot{Ca}\\ \ddot{Fe}^2\end{matrix}\right\}O^{10}$,—

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ding to Komonen).

$$\left.\begin{matrix}\overset{\text{IV}}{Si^2}\\ Na\\ \overset{\text{III}}{Al}\end{matrix}\right\} O^6.H^2O.$$

2. (Hemihedral forms.)

$-NiAs^2.NiS^2$ (nickel-glance),—$NiSb^2.NiS^2$ (nickel-

Dimetric System.

Group 3.

O^4 (scheeletine), — $Pb''Mo^{VI}O^4$ (wulfenite; Levy),—

Group 4.

$ZnSeO^4.7H^2O$. (Mitscherlich.)

Group 5.

H^2PO^4,—$(NH^4)H^2AsO^4$. (Mitscherlich.)

Group 6.

,—$2NH^3.Ag^2CrO^4$. (Mitscherlich.)

Group 7.

uranite), — $Ca''(U^{VI}O^2)^2P^2O^8.8H^2O$ (lime-uranite).

Group 8.

bell.)

Group 9.

).

Hexagonal System.

Group 10.

ium (Breithaupt),— Osmium, — Iridium, — Palla-

Group 11.

(magnesite),—$\left.\begin{matrix}\frac{1}{2}Mg\\ \frac{1}{2}Ca\end{matrix}\right\} CO^3$ (dolomite),—$MnCO^3$ (dial-

CO^3 (spathic iron ore).

enheim.)

Group 12.

Group 13.

$-CaS^2O^6.4H^2O$,—$PbS^2O^6.4H^2O$. (Heeren.)

Group 14.

$PbCl^2.3Pb^3P^2O^8$ (pyromorphite), — $PbCl^2.3Pb^3As^2O^8$

Trimetric System.

Group 15.

Group 16.

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Group 17.

a. $CaCO^3$ (arragonite),—$BaCO^3$ (witherite),—$SrCO^3$ (strontianite),—PbCO
site),—$FeCO^3$ (junkerite; Dufrénoy).
b. KNO^3.
c. $(Cu^2S.2PbS).Sb^2S^3$ (bournonite; G. Rose).

Group 18.

a. $BaSO^4$ (heavy spar),—$SrSO^4$ (cœlestin),—$PbSO^4$ (anglesite; Mitscher
b. $KClO^4$,—$KMnO^4$,—NH^4ClO^4,—$(NH^4)MnO^4$. (Mitscherlich.)

Group 19.

a. Na^2SO^4,—Na^2SeO^4,—Ag^2SO^4,—Ag^2SeO^4. (Mitscherlich.)
b. $BaMn^2O^5$. (Mitscherlich.)

Group 20.

a. K^2SO^4,—K^2SeO^4,—K^2CrO^4,—K^2MnO^4. (Mitscherlich.)
b. $(NH^4)^2SO^4.H^2O$. (Mitscherlich.)

Group 21.

a. $MgSO^4.7H^2O$,—$ZnSO^4.7H^2O$,—$NiSO^4.7H^2O$,—$MgSeO^4.7H^2O$,—ZnSeO
(Mitscherlich.)
b. Sb^2S^3 (v. Kobell),—As^2S^3.

Group 22.

$NaPO^3.2H^2O$,—$NaAsO^3.2H^2O$. (Mitscherlich.)

Monoclinic System.

Group 23.

a. Sulphur.—*b.* $KHSO^4$,—$KHSeO^4$. (Mitscherlich.)

Group 24.

$CaSO^4.2H^2O$,—$CaSeO^4.2H^2O$ (Mitscherlich),—$FeSO^4.2H^2O$. (Graham

Group 25.

$MgSO^4.7H^2O$,—$ZnSO^4.7H^2O$,—$CoSO^4.7H^2O$,—$NiSO^4.7H^2O$,—$FeSO^4.7$
$MgSeO^4.7H^2O$,—$CoSeO^4.7H^2O$. (Mitscherlich.)

Group 26.

$FeSO^4.6H^2O$,—$CoSO^4.6H^2O$,—$MnSO^4.6H^2O$,—$CoSeO^4.6H^2O$. (Mitscher

Group 27.

$MgK^2S^2O^8.6H^2O$,—$Mg(NH^4)^2S^2O^8.6H^2O$,—and similar double salts co
calcium, nickel, cobalt, iron, manganese, zinc, and copper.

Group 28.

$Na^2SO^4.10H^2O$,—$Na^2SeO^4.10H^2O$,—$Na^2CrO^4.10H^2O$. (Mitscherlich.)

Group 29.

$(NH^4)^2HPO^4$,—$(NH^4)^2HAsO^4$. (Mitscherlich.)

Group 30.

$Na^2HPO^4.12H^2O$,—$Na^2HAsO^4.12H^2O$. (Mitscherlich.)

Group 31.

a. $Na^2B^4O^7.10H^2O$ (borax).—*b.* (Ca; Mg) SiO^3 (augite).

Triclinic System.

Group 32.

$MnSO^4.4H^2O$,—$MnSeO^4.4H^2O$,—$ZnSeO^4.4H^2O$,—$CoSeO^4.4H^2O$. (Mitsche

Group 33.

$CuCO^4.5H^2O$,—$CuSeO^4.5H^2O$,—$MnSeO^4.5H^2O$. (Mitscherlich.)

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odies occurring more than once in this table are dimorphous or trimorphous.
o each group of isomorphous bodies in the dimetric, trimetric, monoclinic, and inic systems, there corresponds a particular pyramid with its prisms and domes, to each group in the hexagonal system, a particular rhombohedron.
perfectly exact accordance of the crystalline forms of two chemically different es, occurs perhaps only in the monometric system. Bodies of the same group ch crystallise in other systems generally exhibit small differences in the correspond- angles. Thus, the angles of the terminal edges of the rhombohedrons of calcspar, logite, and the other isomorphous carbonates of group 11, exhibit the following rences:—

		R : R in terminal edges
Calcspar	$CaCO^3$	105° 5′
Dolomite	$\left\{\begin{matrix}Ca\\Mg\end{matrix}\right\}CO^3$	106° 15
Diallogite	$MnCO^3$	106° 51′
Spathic iron	$FeCO^3$	107° 0′
Magnesite	$MgCO^3$	107° 25′
Calamine	$ZnCO^3$	107° 40′.

n arragonite and the carbonates isomorphous therewith (group 17, *a*), the angles : ∞P in the macrodiagonal principal section, and P∞ : P∞ in the basal principal ion, have the following values:

		∞P : ∞P	P∞ : P∞
Arragonite	$CaCO^3$	63° 44′	71° 33′
Witherite	$BaCO^3$	61° 30′	73° 6′
Strontianite	$SrCO^3$	62° 44′	71° 48′
Cerusite	$PbCO^3$	62° 46′	71° 47′.

erfect equality in the corresponding angles of crystals is not always found, even in monometric system. The simpler forms of that system, namely, the cube, octa- ron, and rhombic dodecahedron, do not, of course, admit of any variation in the les; but the remaining forms, which are expressed by formulæ containing finite erical coefficients, viz. mOm, mO, $mO\infty$, and mOn, have different angles, according he numerical values of those coefficients; and, consequently, crystals of two dif- nt substances crystallising in one of these forms may exhibit slight differences in r angles, as well as isomorphous crystals belonging to other systems. With regard he three simpler forms of the monometric system, it may be observed that all bodies ch crystallise in them may be regarded as isomorphous in a certain sense, inasmuch all these forms are derivable one from the other; nevertheless, some bodies are e disposed to crystallise in one form than in the other, and a further distinction is rded by the cleavage; thus, zinc-blende, ZnS, cleaves parallel to the faces of a nbic dodecahedron; galena, PbS, parallel to the faces of a cube. Such bodies, in e of their similarity of form and atomic constitution, cannot be regarded as strictly norphous, at least in the same degree as NaCl and KCl, which agree in the direc- of their cleavage as well as in their form.
rom the similarity of form of two compounds, the isomorphism of certain of their stituents may often be inferred. If a compound, $a + b + c$, is isomorphous with ther, consisting of $a + b + d$, it may be concluded that c is isomorphous with d. example, the isomorphism of K^2PtCl^6 and K^2IrCl^6 leads to the conclusion that inum and iridium are isomorphous. In this manner, the isomorphism of the fol- ing groups of elements may be inferred:

. *Monometric Metals and Metalloids.* Carbon (diamond), phosphorus, potassium, um, titanium, cadmium, lead, iron, copper, silver, gold, platinum, palladium, iridium, zinc (Table I, group 1, *a*),—manganese, calcium, lithium, ammonium, nickel, cobalt , and 1, *c*),—osmium (1, *i*).
. *Hexagonal Metals.* Arsenic, antimony, tellurium, osmium, iridium, palladium, nuth.
. Sulphur, selenium (1, *b*),—chlorine, iodine, bromine, fluorine, cyanogen, arsenic (?) *c*),—oxygen (1, *e*).
n like manner, the isomorphism of certain groups of elements may be inferred from of compounds in which they may be supposed to exist; thus, from the isomorphism he corresponding phosphates and arsenates, regarded as compounds of metallic oxides, P^2O^5 and As^2O^5, *e. g.* $2Na^2O.H^2O.P^2O^5 + 24H^2O$ and $2Na^2O.H^2O.As^2O^5 + 24H^2O$, isomorphism of phosphoric and arsenic anhydrides may be inferred.
he isomorphism of different elements and groups of elements is, however, most pletely shown by their capability of replacing one another in composition in various

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proportions, and without any alteration of crystalline form. Thus, in the alums, wh general formula is $MR'''(SO^4)^2.12H^2O$ the monatomic radicle, M, may be composed potassium, sodium, ammonium, &c., and the triatomic radicle, R, of aluminium, ferricu manganicum, chromicum, &c., in the most various proportions, the form, all the whi remaining the same as that of common potash-alum, $KAl(SO^4)^2.12H^2O$. Numberl examples of this isomorphous replacement are found among natural minerals; inde it is but rarely that any mineral is found in which the principal constituents are r more or less replaced by isomorphous substances. Striking examples of it are afford by the spinels (p. 397, and group 1, *g*, Table I, p. 424), and by the garnets (1, *l*, p. 424

Relations between Crystalline Form and Atomic Volume.—Complete isomorphi between two compounds implies the fulfilment of three conditions, viz.:

1. Similar atomic constitution.
2. Similar crystalline form.
3. Equal atomic volumes of the several constituent elements.

By the volume of an atom, we understand, as explained in the article Atom Volume (i. 440), the space occupied by the solid atom itself, together with a porti of the space which separates it from the intervening atoms: that is to say, the size, rather the radius, of the atom (regarded as spherical) is supposed to include half t distance which separates it from the contiguous atoms. The atomic volume of a su stance, according to this definition, is proportional to its atomic weight divided its specific gravity $\frac{a}{s}$. It is clear that equal numbers of atoms similarly disposed w not *necessarily* produce the same external form, unless the corresponding atoms in t two bodies are equal or at least proportional in volume.

Two or more bodies in which all three of the above conditions of equality are f filled, are isomorphous in the stricter sense. The fulfilment or non-fulfilment of all some of these conditions gives rise to eight different cases of similarity or dissimilar of constitution, which may be enumerated as follows:

Crystalline form.	Atomic constitution.	Atomic volume.		
a. equal	equal	equal	Isomorphous in the narrower sense	Isomorphous in the wider sense
			Isotomous	
b. equal	equal	unequal	Homœomorphous	
c. equal	unequal	equal		
d. equal	unequal	unequal		
e. unequal	equal	equal	Heteromorphous	Anisomorphous in the wider sense
f. unequal	equal	unequal		
g. unequal	unequal	equal		
h. unequal	unequal	unequal	Anisomorphous in the narrower sense; Anisotomous	

The following table exhibits the atomic volumes of a number of bodies arrang according to similarity of crystalline form and atomic constitution. The first colun of figures headed $\frac{a}{s}$, gives the quotient of the atomic weight divided by the speci gravity (the atomic weights being those of the oxygen scale, O = 200); the seco gives the atomic volumes referred to that of carbon 44, as unity; the third, head "theoretical," shows what the value of $\frac{a}{s}$ would be in each case if it were an exa multiple of 44.

* Compounds containing indefinite proportions of isomorphous elements are represented in this wo by formulæ in which the isomorphous elements are separated by semicolons: *e.g.* alum, in which t potassium is partly replaced by ammonium, is expressed by the formula, $(K; NH^4)\ Al(SO^4)^2.12H^2$ In many works such compounds are represented by formulæ like $\left.\begin{matrix}K\\NH^4\end{matrix}\right\}Al(SO^4)^2.12H^2O$; but t is objectionable, since, according to ordinary usage, it would imply that the molecule contains an ato of potassium as well as an atom of ammonium, whereas the real meaning is that the potassium a ammonium are present in such quantities as together to make up a monatomic atom or molecule.

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TABLE II.

Atomic Volumes of Isomorphous Bodies.

			Atomic volume.		
			$\frac{a}{s}$	44 = 1.	Theoretical.
	I. Elements.				
	a. *Monometric.*				
1	Carbon (Diamond)	C	44	1	44
2	Iron	Fe	90	2	88
	Manganese	Mn	88	2	88
	Nickel	Ni	88	2	88
	Cobalt	Co	88	2	88
	Copper	Cu	88	2	88
3	Platinum	Pt	114	$2\frac{1}{2}$	110
	Palladium	Pd	114	$2\frac{1}{2}$	110
	Osmium	Os	114	$2\frac{1}{2}$	110
	Iridium	Ir	114	$2\frac{1}{2}$	110
	Rhodium (?)	Rh	114	$2\frac{1}{2}$	110
	Titanium	Ti	112	$2\frac{1}{2}$	110
	Zinc	Zn	116	$2\frac{1}{2}$	110
4	Lead	Pb	228	5	220
5	Gold	Au	128	3	132
	Silver	Ag	130	3	132
6	Phosphorus	P	222	5	220
7	Sodium	Na	292	$6\frac{3}{4}$	297
8	Potassium	K	583	$13\frac{1}{2}$	594
	b. *Hexagonal.*				
9	Arsenic	As	160	$3\frac{3}{4}$	165
0	Antimony	Sb	240	$5\frac{1}{2}$	242
1	Bismuth	Bi	270	$6\frac{1}{4}$	275
	c. *Bodies probably crystallising in similar forms.*				
2	Bromine	Br	326	$7\frac{1}{2}$	330
	Chlorine	Cl	320	$7\frac{1}{3}$	330
	Iodine	I	320	$7\frac{1}{3}$	330
	Cyanogen	Cy	315	$7\frac{1}{2}$	330
	II. Proto-chlorides, bromides, and iodides.				
	Monometric.				
3	Chloride of silver	AgCl	320	$7\frac{1}{3}$	330
	Chloride of sodium	NaCl	325	$7\frac{1}{3}$	330
4	Bromide of silver	AgBr	367	$8\frac{1}{4}$	363
5	Chloride of ammonium	NH^4Cl	437	10	440
6	Chloride of potassium	KCl	481	11	484
7	Iodide of silver	AgI	522	12	528
8	Bromide of potassium	KBr	608	14	616
9	Iodide of potassium	KI	667	15	660
	III. Protoxides, $\overset{\prime\prime}{M}mO$.				
	Monometric.				
0	Magnesia	MgO	156	$3\frac{1}{2}$	154
	Cupric oxide	CuO	156	$3\frac{1}{3}$	154
1	Manganous oxide	MnO	188	4	176
	Zinc-oxide	ZnO	180	4	176
2	Cadmium-oxide	CdO	230	5	220
3	Lead-oxide	PbO	306	7	308
4	Strontia	SrO	330	$7\frac{1}{2}$	330
5	Baryta	BaO	402	9	396
6	Silver-oxide	Ag^2O	352	8	352
7	Soda	Na^2O	278	6	264
8	Potash	K^2O	446	10	440

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TABLE II.

Atomic Volumes of Isomorphous Bodies—continued.

		Atomic volume.		
		$\frac{a}{s}$	44 = 1.	T re
IV. Proto-sulphides and Selenides.				
Monometric.				
29	Manganese-blende . . . . . MnS	272	6	
30	Zinc-blende . . . . . ZnS	296	$6\frac{1}{2}$	
31	Selenide of lead . . . . . $PbSe$	406	9	
	Galena . . . . . PbS	386	9	
32	Silver-glance . . . . . Ag^2S	432	10	
V. Dioxides.				
Dimetric.				
33	Titanic anhydride . . . . . TiO^2	260	6	
	Stannic anhydride . . . . . SnO^2	270	6	
VI. Sesquioxides.				
a. *Monometric.*				
34	Antimonic oxide . . . . . Sb^2O^3	662	15	
	Arsenious oxide . . . . . As^2O^3	664	15	
b. *Hexagonal.*				
35	Alumina . . . . . Al^2O^3	362	$8\frac{1}{2}$	
	Ferric oxide . . . . . Fe^2O^3	372	$8\frac{1}{2}$	
36	Chromic oxide . . . . . Cr^2O^3	384	9	
VII. Carbonates.				
a. *Trimetric.*				
37	Arragonite . . . . . $CaCO^3$	426	10	
38	Strontianite . . . . . $SrCO^3$	512	$11\frac{1}{2}$	
	Cerusite . . . . . $PbCO^3$	516	$11\frac{1}{2}$	
39	Witherite . . . . . $BaCO^3$	576	13	
b. *Hexagonal.*				
40	Zinc-spar . . . . . $ZnCO^3$	352	8	
	Magnesite . . . . . $MgCO^3$	356	8	
41	Spathic iron ore . . . . . $FeCO^3$	378	$8\frac{1}{2}$	
42	Diallogite . . . . . $MnCO^3$	400	9	
	Dolomite . . . . . $\left.\begin{matrix}\frac{1}{2}Mg\\\frac{1}{2}Ca\end{matrix}\right\}CO^3$	402	9	
43	Calcspar . . . . . $CaCO^3$	460	$10\frac{1}{2}$	
VIII. Nitrates.				
a. *Hexagonal.*				
44	Nitrate of potassium . . . . . KNO^3	602	$13\frac{1}{2}$	
45	Nitrate of sodium . . . . . $NaNO^3$	484	11	
b. *Monometric.*				
46	Nitrate of strontium . . . . . SrN^2O^6	916	21	
	Nitrate of lead . . . . . PbN^2O^6	942	$21\frac{1}{2}$	
47	Nitrate of barium . . . . . BaN^2O^6	1024	23	
IX. Magnesian Sulphates, $M''SO^4.7H^2O$.				
Trimetric.				
48	Sulphate of nickel . . . . $NiSO^4.7H^2O$	1724	39	
	Sulphate of zinc . . . . $ZnSO^4.7H^2O$	1760	40	
	Sulphate of magnesium . . . $MgSO^4.7H^2O$	1786	$40\frac{1}{2}$	

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TABLE II.

of Isomorphous Bodies—continued.

ian Sulphates, .6H²O. *nic.*	Atomic volume. $\frac{a}{s}$	44 = 1.	Theoretical.
. . . . .	2526	57½	2530
. . . . .	2578	58⅓	2574
. . . . .	2558	58⅓	2574
. . . . .	2578	58⅓	2574
. . . . .	2632	60	2640
. . . . .	2604	59	2596
. . . . .	2840	64½	2838
$(SO^4)^2.12H^2O$.			
tric.			
. . . . .	3380	77	3388
. . . . .	3472	79	3476
. . . . .	3472	79	3476
. . . . .	3472	79	3476
lphides and Arsenides.			
etric.			
. . . . FeS^2	292	6⅔	286
. . . . Co^2S^3	424	9⅔	418
. . . . $CoAs^2$	414	9½	418
. . . . $CoAs^3$	530	12	528
. . . . $NiAs^2S^2$	658	15	660
. . . . $CoAsS^2$	660	15	660
etric.			
. . . . FeS^2	306	7	308
. . . . $Fe^3As^2S^2$	692	16	704
. . . . .	195	4½	198
. . . . .	201·8	4½	198

this table leads to the following general conclusions.
bracketed together in the table can be regarded as
us; and even among these, there are some whose
of strontium and nitrate of lead (44); magnesio-
monic sulphate (49).

regarded as isomorphous are in reality only homœo-
omic volumes differ considerably. Such is the case
gnesia and manganous oxide; soda and silver-oxide;
manganese-blende and zinc-blende; nitrate of potas-
atomic volumes of these homœomorphous bodies are,
y simple proportions, as in the following examples:—

. 1	Arsenic 3
. 2	Phosphorus . . . 4
. 2	Soda (anhydrous) . . 3
. 3	Silver-oxide . . . 4

us in the free state, are not always so in combination.
, manganese, nickel, &c.; but many copper-salts are
ponding salts of the other metals just mentioned.
e isomorphous in the free state, but by no means in
any bodies are isomorphous in their compounds, but
morphous, in the free state: thus phosphorus and
he free state, but isomorphous in their compounds;
nd antimony, magnesia and manganous oxide, potas-
er-oxide, are homœomorphous in the separate state,

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but isomorphous in some of their compounds. This apparently paradoxical relatio may arise either from dimorphism—the substances in question crystallising in th free state in a form different from that which they assume in combination—or fro variation of atomic volume. In fact, the atomic volume of a compound is, in nearl all cases, less than the sum of the atomic volumes of its elements in the free state, th condensation being greater as the affinity is stronger. Hence it may happen tha elements whose atomic volumes in the free state are unequal, may assume equa volumes in combination, and therefore yield isomorphous compounds.

4. Bodies of different atomic volume often crystallise in the same form, and ar capable of crystallising together. Gold and silver, whose atomic volumes are nearl as 1 : 2, crystallise together in very variable proportions; so likewise do chloride o sodium, chloride of ammonium, and iodide of potassium, whose atomic volumes are t one another as 3 : 4 : 6. It is only, however, in the monometric system that perfec similarity of crystalline form is exhibited by substances of different atomic volume; i crystals belonging to other systems, difference of atomic volume in bodies of simila atomic constitution, is always accompanied by a slight difference in the magnitude o certain angles, as may be seen by comparing the angles and atomic volumes of th several members of the calcspar and arragonite groups (pp. 427, 430), the obtuse ter minal angles in the former, and the angles $P\infty : P\infty$ in the latter diminishing as th atomic volume increases. This relation between atomic volume and crystalline form is further shown by the observation of Mitscherlich, that the angle of a rhombohedro of calc-spar diminishes when the crystal is heated: for the specific gravity is thereby diminished, and consequently the atomic volume increased.

5. An interesting example of homœomorphism is afforded by nitrate of potassium which is dimorphous, having a rhombohedral form similar to that of calcspar, and a trimetric form like that of arragonite. Its angles in these two forms are as follows:

	Atomic volume.	Terminal angle of rhomb. (nearly).
Hexagonal Nitre KNO^3	27	106° 30′
		∞P $P\infty$
Trimetric Nitre KNO^3. . . .	27	61·0′ 70° 4′

In its rhombohedral form, this substance agrees very nearly with dolomite and dial logite, the terminal angles of which are 106° 15′ and 106° 51′ respectively, and whos atomic volumes are equal to 9: hence it appears that two substances whose atomi volumes are as 1 : 3 may crystallise nearly in the same form. Similar relations though not quite so close, may be traced between the atomic volumes and crystallin forms of rhombic nitre and arragonite.

The relations between the atomic volumes and crystalline forms of different sub stances are, however, far from being established on a perfectly satisfactory basis indeed the general conclusions of different observers relating to this subject are i some instances directly contradictory to each other: the discrepancies doubtless aris in many instances from the want of exact determinations of crystalline form, and mor especially of specific gravity.

Schröder, to whose observations, together with those of Kopp, the results detailed in the preceding pages are mainly due, has recently made further experiments on the relations between chemical constitution and specific gravity, and has arrived at the following conclusions respecting the atomic volumes of isomorphous bodies. When two different elements or groups of elements, *A* and *B*, unite with other elements or groups of elements, *C*, *D*, *E*, &c., forming the compounds *AC* and *BC*, *AD* and *BD*, *AE* and *BE*, &c., belonging to the same type and isomorphous by pairs, the differences of the atomic volumes of *AC* and *BC*, *AD* and *BD*, *AE* and *BE*, &c., are always equal; but if the pairs of compounds thus formed are not isomorphous, or if they are isomorphous, but belong to different types, then the differences of atomic volume are unequal, and different from what they would be if the pairs were isomorphous or belonged to the same type. If bodies of equal atomic volume be denominated isosteric, and analogous pairs of compounds exhibiting equal differences of atomic volume, parallelosteric, the preceding law may be more shortly stated as follows:—*Pairs of compounds which are isomorphous and analogous are likewise parallelosteric.* This law has been confirmed by Tschermak. (Wien. Akad. Ber. xlv. [2] 603.)

Schröder further concludes that the volume of any element, which, in the isomorphous nitrates, chlorides, bromides, iodides or sulphides, is the greater of the two constituting a pair, is condensed in the isomorphous sulphates, carbonates, silicates, and aluminates, to a comparatively greater amount, so as often to become the lesser of the two. Thus the atomic volumes of chloride, bromide, and nitrate of potassium (calculated on the hydrogen-scale) of atomic weights, are greater by 2·7 to 2·5 than those of the corresponding ammonium salts, whereas that of sulphate of ammonium is greater by 2·5 than that of sulphate of potassium.

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With regard to the elements, Schröder finds that isosterism is accompanied quite as quently, if not more so, by heteromorphism as by isomorphism; but that elements ose atomic volumes are to one another as 1 : 2 (like silver and gold) are often norphous. In oxides and salts also, Schröder finds that isosterism is associated with norphism less frequently than with heteromorphism.

The relations between the atomic volumes and the proportions of the axes (which ermine the angles) in series of homœomorphous bodies, are also, according to röder's recent observations, less constant than was formerly supposed. It is true t the limiting members of each series with regard to the proportions between the s, are also the limiting members with regard to the atomic volumes; but the rmediate terms do not generally exhibit the regular relation between axial propor- s and the atomic volumes which has been noticed in the calcspar and arragonite ups. According to Tschermak, on the contrary (Wien. Akad. Ber. xlv. [2], 603; resber. 1862, p. 9), homœomorphous bodies of analogous composition form the e series with regard to their axial relations, as with respect to their atomic volumes. mpare i. 449–452.)

Polymeric Isomorphism. This term is applied by Scheerer to express the fact 1 at. of an element may in some cases be replaced by two or more atoms of ther, or, generally, m atoms of one element by n atoms of another, or by a group toms of other elements, without essential alteration of crystalline form. Instances his kind of isomorphism are afforded by the sulphides of lead and silver (PbS Ag^{2}S), by the sulphide and chloride of silver (Ag^{2}S and Ag^{2}Cl^2), by numerous norphous chlorides and cyanides, in which the single atom Cl and the group CN harge equivalent functions; and by the isomorphous salts of potassium and ammo- n, in which NH^4 is equivalent to K. Numerous other examples may be found ongst organic compounds: thus the acetate and butyrate of copper, C^{2}H^{3}O^{2}Cu, and ^{7}O^{2}Cu, are isomorphous, and the sulphates of many organic bases, *e. g.* ethylamine, hylamine, conine, unite with sulphate of aluminium, forming alums isomorphous n common potash-alum.

Natural minerals likewise afford examples of this kind of isomorphism, to which ntion has been particularly directed by Scheerer. Thus, certain varieties of ite and hornblende contain alumina, while others, which are free from alumina, tain a larger proportion of silica, the substitution taking place, according to Scheerer, he proportion 1 at. Al^2O^3 to 1 at. SiO^2 (or $3Al^2O^3$ to $2Si^3O^3$), but, according to melsberg, in the ratio of $2Al^2O^3$ to $3SiO^2$ (p. 169). Another instance is afforded the minerals cordierite (dichröite), and aspasiolite, which are isomorphous and e in composition, excepting that, according to Scheerer, 1 at. magnesia in the ner is replaced by 3 at. water in the latter. According to the formulæ given by mmelsberg, however (*Mineralchemie*, pp. 768, 834), viz.,

Cordierite, $6MgO.6(Al; Fe)^2O^3.15SiO^2$.
Aspasiolite, $4MgO.6(Al; Fe)^2O^3.15SiO^2.8H^2O$,

ppears that 4 at. water in the latter take the place of 1 at. magnesia in the former. or a full development of the theory of polymeric isomorphism as applied to minerals, Scheerer (Handw. d. Chem. iv. 170).—On isomorphism in general, see Mitscher- h (Ann. Ch. Phys. [2], xiv. 172; xix. 350; xxiv. 264 and 355).—Breithaupt. J. pr. m. iv. 249).—Persoz, Ann. Ch. Phys. [2], lx. 119).—Brooke (Phil. Mag. [3], xii.).—Johnston (*ibid.* xii. 325 and 480; xiii. 405).—Schaffgotsch (Pogg. Ann. ii. 335).—H. Kopp (*ibid.* liii. 446).—Hankel (*ibid.* lv. 479).—Frankenheim pr. Chem. xxvi. 257 and 263).—Wallmark (*ibid.* xxxi. 169).—Nicklès (Compt. l. xxvii. 611).—Pasteur (*ibid.* xxviii. 477).—G. Rose (Pogg. Ann. lxxvi. 75; i. 143).

ISONITROPHENIC ACID. See PHENIC ACID.

ISOPHANE. Syn. with FRANKLINITE (ii. 707).

ISOPRENE. C^5H^8.—A very volatile hydrocarbon, polymeric with caoutchin 757), obtained, together with the latter and other less volatile products, by the dry illation of caoutchouc and gutta percha. After repeated rectification over sodium, oils between 37° and 38°, has a specific gravity of 0·6823 at 20°, and vapour- sity = 2·40 obs.; 2·36 calc. After keeping for a month, it became thickened, and uired a bleaching action, in consequence of the absorption of ozone: on subse- ntly distilling it, the ozone acted violently on the hydrocarbon, and the residue denly solidified to a white amorphous mass having the composition $C^{10}H^{16}O$. r. Williams, Proc. Roy. Soc., x. 516.)

ISOPURPURIC ACID. *Picrocyamic acid.* $C^8H^5N^4O^6$. (Hlasiwetz, Ann. Ch. rm. cx. 289; Jahresber. 1860, p. 455. Bayer, Bull. Acad. roy. Belgique, [2] vii. 8.)—An acid, isomeric with purpuric acid, but, like the latter, not known in the free

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state. The potassium-salt is obtained by the action of cyanide of potassium on pic acid:

$$C^6H^3N^3O^7 + 3CNK + 3H^2O = C^8H^4KN^5O^6 + CO^2 + NH^3 + 2KHO.$$

When a solution of 2 pts. cyanide of potassium (prepared by Liebig's process, 215), in 4 pts. water, warmed to about 60°, is mixed with a solution of 1 pt. pic acid in 9 pts. water, the mixture being constantly stirred, a strong odour of ammo and hydrocyanic acid is given off, and the liquid solidifies on cooling to a soft cryst line pulp; and on straining this mass upon linen, pressing it between bibulous pap heating and triturating the red-brown crystalline residue with a small quantity water, then throwing it on a filter, washing it with cold water, again pressing, d solving it in a large quantity of boiling water, and leaving the hot-filtered solution crystallise, *isopurpurate of potassium* separates, as a metal-green film, and in brown-r crystalline scales, exhibiting a green colour by reflected light. It dissolves sparing in cold, more easily in boiling water, imparting a very deep purple colour, and precipitated from a concentrated solution by carbonate of potassium,—which circu stance may be taken advantage of in the preparation of the salt, if, in consequence the presence of impurities, it does not separate spontaneously as above described. T salt dissolves also in dilute *alcohol*. When heated to about 215°, it decomposes, w somewhat strong detonation, slight appearance of fire, and formation of a grey clou it may also be exploded by contact with sulphuric acid. Its solution is precipitat by salts of barium, lead, mercury, and silver; not by those of calcium, strontiu copper, or zinc. The solution does not give the ordinary reactions of cyanogen.—T salt dried at 100° contains $C^8H^4KN^5O^6$.

The *ammonium-salt*, $C^8H^4(NH^4)N^5O^6$ (at 100°), separates in metallic-shining, da green crystals, on adding a solution of chloride of ammonium to a very concentrat solution of the potassium-salt. It is easily recrystallised, and then forms small wed shaped crystals, brown-red by transmitted and green by reflected light. It is ve slightly soluble in cold water, more easily in boiling water, forming a deep-pur solution. When heated on platinum-foil, it deflagrates like gunpowder.

The *barium-salt*, $C^{16}H^8Ba''N^{10}O^{12}$ (at 100°), separates on adding chloride of bari to a solution of the potassium-salt, as a nearly cinnabar-coloured precipitate, sparin soluble in cold water, perfectly soluble, with purple colour, in hot water. In the state it has a light-green metallic lustre, but when triturated becomes red again, deflagrates with a dazzling green light.

On mixing the hot concentrated solutions of cyanide of barium and picric acid, t liquid acquires a blood-red colour, and deposits a dark-coloured precipitate which resolved by hot water into a red-brown powder with green lustre, soluble in water, a a substance containing a large quantity of carbonate of barium, insoluble therein.

The *calcium-salt*, $C^{16}H^8Ca''N^{10}O^{12}.3H^2O$, separates, after 24 hours, from a mixture a hot-saturated solution of the ammonium-salt with chloride of calcium, in gre metallic-shining needles, which give off their water at 140°.

Lead-salt, $C^{16}H^8Pb''N^{10}O^{12}$.—The solution of the potassium-salt is completely preci tated by neutral acetate of lead; the precipitate, which is at first brown red and ve bulky, soon becomes dark violet-brown and pulverulent; it dissolves with pur colour in boiling water, and the solution deposits slender microscopic needles, whi after drying, are light brown-red with greenish iridescence, and detonate very sharp when heated. It is not completely decomposed by sulphydric acid, and on boiling t remaining mass with water, a yellowish-red solution is obtained, which deposits shini brown crystalline tufts having the composition of the original salt.

The *potassium-salt*, $C^8H^4KN^5O^6$ ($C^8H^2KN^5O^5$, according to Bäyer), has been alrea described.

The *silver-salt*, $C^8H^4AgN^5O^6$ (at 100°), separates from a solution of the potassiu salt, on addition of nitrate of silver, as a brown precipitate, which dries up to a dar green mass possessing metallic lustre. It detonates when heated, and dissolves wi purple colour in a large quantity of boiling water.

The *sodium-salt*, $C^8H^4NaN^5O^6$, is obtained, like the potassium-salt, by the action cyanide of sodium on picric acid. It is dark-green with metallic lustre, dissolves water much more easily than the potassium-salt, and is more difficult to crystallis the solution is red.

The *strontium-salt* is obtained by adding nitrate of strontium to a solution of t potassium-salt, as a green, pulverulent, indistinctly crystalline precipitate, whi deflagrates with a red flame when heated.

Hlasiwetz regards isopurpuric acid as dibasic, and the monometallic salts abo described as acid salts. The neutral salts have not been obtained in definite foru but the solution of the monopotassic salt, mixed with caustic potash, acquires a dar violet colour, and yields a precipitate which soon decomposes and turns brown. similar change of colour, followed by rapid decomposition, is produced on triturati

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n-salt with baryta-water. All the salts are very much like the corresponding s; the ammonium-salt, according to Grailich's determinations, exactly re- urpurate of ammonium (*murexid*), in its crystalline form and optical

YRE (from *ἴσος*, equal, and *πῦρ*, fire, because its appearance when fused is as in the natural state). A silicate of calcium, aluminium, and iron, found t, near Penzance, in Cornwall, in a quartzose granite, with tourmalin and tin n breccia, on the Calton Hill, Edinburgh. It bears considerable resemblance n, having a conchoïdal fracture, no cleavage, a greyish-black to velvet-black d vitreous lustre. Specific gravity, 2·912; hardness 6 to 6·5, nearly equal to hoclase. Melts before the blowpipe to a black magnetic globule. Contains, to Turner's analysis (Ed. N. Phil. J. iii. 263), 47·69 silica, 13·91 per cent. 15·43 lime, 20·07 ferric oxide, and 1·94 cupric oxide (loss 1·56 per cent.), early with the formula $Ca^2O.Al^4O^3.3SiO^2$, which is essentially the same as bradorite; but part of the iron in the mineral appears to be in the state of and as long as this amount remains undetermined, the formula cannot be certainty.

ARTARIC ACID and **ISOTARTRIDIC ACIDS.** See TARTARIC IVATIVES OF.

IBROMHYDRIN. Syn. with tribromide of allyl (i. 141).

REBENTHENE. See TURPENTINE.

OLUMITE. A laminated granular quartz-rock, in which diamonds are found: it probably owes its lamination to talc or mica. It occurs in the Brazil and the Ural; also in Georgia and North Carolina, where a few have been found. (Dana, ii. 24.)

ONIC ACID. $C^5H^6O^4$.—An acid obtained, together with citraconic acid y the dry distillation of citric acid. It bears a close resemblance to citraconic differs from it in solubility and in its reactions with nitric acid and with It is prepared by heating citric acid in a retort by a spirit-lamp, care being the heat is applied at the bottom, and not on the sides, as in the latter case would be converted into citraconic acid. The distillation is continued until atic vapours appear. The oily distillate is then dissolved in six parts of ter, and evaporated to crystallisation: the crystals which are first formed itaconic acid; citraconic acid, which is always formed at the same time, issolved in the mother liquor. Frequently the distillate solidifies on cooling. e the crystals are pressed between bibulous paper on a plate at 100°, and then aper moistened with absolute alcohol, and lastly recrystallised from water.

acid is inodorous, and has a strongly acid taste: when crystallised from as the form of a rhombic octahedron. It dissolves in 17 pts. of *water* at 20°, ch more soluble at a higher temperature. It is soluble in *alcohol* and in *ether*. at 161° to a colourless liquid which crystallises on cooling; when further decomposes into citraconic anhydride and water. Unlike citraconic acid, yield mesaconic acid when treated with nitric acid. When treated with nd water, it takes up 2 at. bromine without evolution of hydrobromic acid, an acid having the composition of dibromo-pyrotartaric acid, $C^5H^6Br^2O^4$, Ann. Ch. Pharm. Supp. i. 338; ii. 111; Cahours, Ann. Ch. Phys. [3], , and called *itadibromosuccinic acid* by Kekulé, *dibromitaconic* Cahours (see PYROTARTARIC ACID, DERIVATIVES OF). Citraconic acid yields r an isomeric acid (Cahours). Itaconic acid treated with *sodium-amalgam* at. hydrogen and forms pyrotartaric acid, $C^5H^8O^4$ (Kekulé).

ates. Itaconic acid is dibasic, forming acid salts, $C^5H^5MO^4$, and neutral $^7M^2O^4$. The neutral itaconates of the alkali-metals do not crystallise. The *sium*-salt is very soluble in water, and crystallises in lustrous laminæ. It is y neutralising the acid with potash, adding a quantity of acid equal to that ken, and evaporating to crystallisation. The alkaline salts are soluble, and precipitates with the soluble salts of lead, mercury, and silver.

s of Itaconic acid. The amides of itaconic acid are not known, excepting *aconamic acid*, which appears to be formed by heating itaconate of ammonium hereby a brownish acid mass is obtained which forms a very soluble salt onium. But some of the corresponding phenylamine-compounds have been d by Gottlieb (Ann. Ch. Pharm. lxxvii. 215), to whose researches the eferred for further details.

aconamide, $C^{17}H^{16}N^2O^2$, is derived from neutral citraconate of phenylamine by two atoms of water:

$$C^{17}H^{20}N^2O^4 = 2H^2O + C^{17}H^{16}N^2O^2.$$

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It is obtained by heating itaconic acid with excess of phenylamine in a retort at a temperature a little above 180°. It crystallises in large thin plates with a pearly lustre.

Phenylitaconamic acid, $C^{11}H^{11}NO^3$, is derived from the acid itaconate of phenylamine by loss of water:

$$C^{11}H^{13}NO^4 - H^2O = C^{11}H^{11}NO^3.$$

It is obtained by evaporating phenylamine to dryness with an excess of itaconic acid, and heating the residue a little above 100°. It forms large colourless needles, more soluble in alcohol than in water. Heated to 160° it is decomposed.

Itaconic Ether. $C^9H^{14}O^4 = C^5H^4(C^2H^5)^2O^4$. Itaconic acid is mixed with alcohol and hydrochloric acid, and the mixture distilled until about a third of the alcohol has passed over: water is then added to the residue, which separates the ether. It is a colourless, inodorous oil with a slight aromatic odour and bitter taste. It boils at 225°, but begins to decompose at this point. E. A.

ITTNERITE. A silicate occurring in monometric crystals, with dodecahedral cleavage, also granularly massive, in the dolerite of the Kaiserstuhl, near Freiberg; in basaltic dolerite at Sasbach; in phonolitic dolerite, with pyrites, titanic iron, and apatite, at Endingen. Hardness = 5·5. Specific gravity = 2·37 to 2·40. Colour dark-bluish or ash grey, or smoky grey. Lustre resinous. Translucent. Fracture imperfectly conchoïdal. When heated in a tube, it gives off a large quantity of water, and before the blowpipe melts easily, with strong intumescence and evolution of sulphurous anhydride, forming a blebby opaque glass. Forms a clear glass with borax. Gelatinises easily with acids.

The composition of the mineral is shown by the following analyses: *a.* by C. Gmelin (Schw. J. xxxvi. 74), *b.* by Whitney (Pogg. Ann. lxx. 442).

	SiO^2	SO^3	Cl	Al^2O^3	Fe^2O^3	CaO	Na^2O	K^2O	Water and loss.*	
a.	34·02	2·86	0·73	28·40	0·61	7·26	12·15	1·56	10·76	= 98·35
b.	35·69	4·62	1·25	29·14	. .	5·64	12·57	1·20	9·83	= 99·94

* Including sulphur undetermined.

According to the latter analysis, ittnerite may be regarded as a mixture of hydrated sodalite and hauyne (p. 15). (Dana, ii. 319; Rammelsberg, *Mineralchemie*, p. 712.)

IWAARITE. A black mineral from Iwaara in Finland, which crystallises in monometric forms, melts before the blowpipe to a black glass, and, according to Thoreld, consists of silica, titanic acid, lime, and ferric oxide: perhaps identical with schorlamite. (Rammelsberg, *Mineralchemie*, p. 887.)

IXIOLITE. A variety of tantalite from Kimito in Finland, containing considerable quantities of manganese and tin.

IXOLITE. A fossil resin found in a bed of bituminous coal at Oberhart, near Glogynitz. It is amorphous, with a fatty lustre and hyacinth-red colour, becoming yellowish when pulverised. It is subtranslucent in thin fragments. Fracture imperfectly conchoïdal in the purer varieties. Specific gravity = 1·008. Hardness = 1. Softens at 76°, but is still tenacious at 100°. (Haidinger, Pogg. Ann. lvi. 345.)

J

JADE. See Nephrite and Saussurite.

JALAP. This name is applied to the roots and tubers of certain plants of the convolvulaceous order, which yield purgative resins. The true or officinal jalap consists of the tubers of *Convolvulus Schiedanus* (or *Exogonia purga*, according to Pereira), which contain a strongly purgative resin called convolvulin, $C^{31}H^{56}O^{16}$ (ii. 15), Kayser's *rhodeoretin*.

Spurious, woody or fusiform jalap, jalap-wood, or jalap-stalks (*Stipites Jalapæ*), the root of *Convolvulus orizabensis*, is sometimes mixed with genuine jalap. Its characteristic principle is jalapin, $C^{34}H^{56}O^{16}$ (Kayser's *pararhodeoretin*, p. 438), a resin homologous with convolvulin, and identical, or nearly so, with scammonin, the active principle of *Convolvulus Scammonia* (p. 438). The experiments of W. Mayer (Ann. Ch. Pharm. xcv. 161) seem to show that both convolvulin and jalapin exist in both kinds of jalap.

JALAPIC ACID. $C^{34}H^{60}O^{18}$? *Scammonic* or *Scammoninic acid.* (W. Mayer, Ann. Ch. Pharm. xcii. 115; xcv. 129. Spirgatis, *ibid.* cxvi. 289.)—An acid produced, with assimilation of water by dissolving jalapin in aqueous solutions of the alkalis or

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aline earths. Jalapin is heated with baryta-water to the boiling point, until the ole is dissolved, and acids no longer form a precipitate in the solution; the baryta hen removed by sulphuric acid; the excess of this acid by hydrate of lead; and the solved lead, by sulphydric acid. The filtrate boiled to remove the sulphydric acid, l evaporated, deposits jalapic acid, which, in case it has become coloured, may be de-orised by treatment with animal charcoal, or by boiling it with a little hydrate of d, and subsequently passing sulphydric acid through the liquid.

Jalapic acid is a translucent, amorphous, shining, yellowish, brittle mass, which s not soften below 100°, and at about 120° melts to a turbid, very hygroscopic syrup. as no smell, but an irritating sweetish taste (Mayer), or a sourish irritating taste, h bitter after-taste (Spirgatis). It has a strong acid reaction; dissolves very ily in *water*, easily also in *alcohol*, less easily in *ether*. It contains, according to mean of Mayer's analyses, 54·4 per cent. carbon and 8·3 hydrogen; according to irgatis, 54·6 carbon and 8·2 hydrogen: hence Mayer deduces the formula $H^{30}O^{15}$, requiring 54·6 carbon and 7·9 hydrogen; the formula above given, which uires 54·0 carbon and 8·0 hydrogen, is perhaps more probable.

Jalapic acid decomposes at about 130°; when heated on platinum foil, it burns with right sooty flame. When a concentrated aqueous solution is stirred for a long time h fuming *hydrochloric acid*, it splits up into jalapinol and glucose (Mayer):

$$2C^{34}H^{60}O^{18} + 7H^2O = C^{28}H^{48}O^7 + 6C^6H^{12}O^6.$$

e jalapic acid obtained from scammony forms jalapinolic acid, instead of jalapinol irgatis; see p. 440). The same decomposition appears to be caused by emulsin ayer). Mayer obtained alphajalapic acid by boiling jalapic acid with dilute acids *nitric acid* jalapic acid is converted into ipomæic and oxalic acids. When melted h *hydrate of sodium*, it gives off hydrogen, and forms jalapinolic and oxalic acids.

Jalapates. Jalapic acid unites with bases, forming salts in which 1, 2, and 3 at. drogen are replaced by the same number of atoms of metal: mixtures of these ferent salts are, however, very apt to form. It displaces carbonic acid from the car-nates of the alkalis and alkaline earths. Even when neutralised with an alkali, it es no precipitate with any metallic salt, except basic acetate of lead. The jalapates amorphous.

Barium-salts. The *monobarytic salt*, $C^{68}H^{116}Ba^2O^{36}$, is obtained by mixing aqueous apic acid with a slight excess of baryta-water, removing the excess of baryta with bonic acid, then warming and evaporating the filtrate. It resembles the tribarytic t, and contains, according to Mayer's analysis, 49·7 per cent. C, 7·6 H, and 8·6 Ba, above formula requiring 49·4 C, 7·1 H, and 8·3 Ba.

The *tribarytic salt*, $C^{68}H^{114}Ba^3O^{36}$, is prepared by boiling jalapin for 4 to 6 hours, h 2 pts. hydrate of barium and 4 pts. water (or mixing it with an equal weight of drate of barium, melted for half an hour in an air-bath, and then heated with water), l passing carbonic acid through the boiling solution, which is then filtered and porated down, and the residue dried at 100° in a current of air. It is an amorphous, utral, slightly-coloured mass, having a slightly irritating, bitter-sweet taste. It melts 100°, and decomposes with intumescence when strongly heated. It is soluble in ter and alcohol, and is not decomposed by carbonic acid (Mayer, Spirgatis). It ntains, according to Mayer, 42·1 per cent. C, 6·0 H, and 21·6 Ba, the preceding mula requiring 43·2 C, 6·0 H, and 21·8 Ba. [Mayer's formula, $C^{68}H^{116}Ba^3O^{35}$, uires 42·4 C, 5·9 H, and 21·3 Ba.]

A salt of intermediate composition, perhaps the *dibarytic salt*, appears also to be med under certain circumstances (Mayer).

Jalapate of lead.—Recently precipitated hydrate of lead dissolves in boiling aqueous apic acid, forming an amorphous, easily soluble salt. When the aqueous acid is iled for a long time with excess of hydrate of lead, a gummy, tumefied, basic salt is med, which is insoluble in water, and very sparingly soluble in alcohol. The aqueous d gives no precipitate with neutral acetate of lead, but copious white flakes with the sic acetate (Mayer, Spirgatis). Ammoniacal acetate of lead, or the basic acetate, rows down, from the aqueous acid, a flocculent precipitate, which may be purified by eated solution in acetic acid, precipitation with ammonia, and washing. After being ied over oil of vitriol, it does not lose weight at 130° (Keller). It contains, ac-ding to Keller's analysis, 31·1 per cent. lead; the formula $C^{68}H^{114}Pb^3O^{36}$ requires 1 per cent. Keller's salt probably contained excess of base.

Alpha-jalapic acid. $C^{28}H^{50}O^{13}$. (W. Mayer, Ann. Ch. Pharm. xcv. 155.)—ien dilute aqueous jalapic acid is boiled for not too long a time with hydrochloric dilute sulphuric acid, one part of the jalapic acid is completely converted into apinol and sugar, another smaller part into alphajalapic acid, which, on cooling, arates out, with the jalapinol, as a soft, brown, semi-crystalline mass. By boiling s mass with baryta-water, removing the jalapinolate of barium which separates on ling, and concentrating the mother-liquor, white silky needles of alphajalapic acid

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are obtained, while jalapinate of barium remains in solution. The needles are purified by recrystallisation from water; then dissolved in boiling water, and decomposed by acetic acid; and the alphajalapic acid, which crystallises out on cooling, is collected and purified by washing, recrystallising from water, acidulation with acetic acid, solution in alcohol, and precipitation with hot water.

Alphajalapic acid forms white, flexible needles, exhibiting a silky lustre under water, melting below 80° to a pale yellow thin oil, and forming a crystalline solid on cooling. It has no smell, but an irritating taste, with sweetish after-taste, and is feebly acid. It dissolves sparingly in cold, more freely in boiling *water*, easily in alcohol and in ether.

When the barium-salt (or the acid itself) is *heated*, it is decomposed, with frothing, and gives off a brown acid oil, which solidifies on cooling, partly in the crystalline form. When treated with *dilute acids*, or boiled with *nitric acid*, or melted with *hydrate of potassium*, it exhibits the same reactions as jalapic acid. In the decomposition with dilute acids, however, only 4 at. sugar are formed to 1 at. jalapinol, whereas jalapic acid (p. 437) yields 6 at. sugar:

$$2C^{28}H^{50}O^{13} + 5H^2O = C^{32}H^{62}O^7 + 4C^6H^{12}O^6.$$

Alphajalapate of barium, prepared as above, forms white, glittering, brittle, crystalline needles, having a sweetish irritating taste, and melting easily, without loss of water, to a thin oil, soluble in water and in alcohol. It contains 10·5 per cent. barium, corresponding with the formula $C^{56}H^{98}Ba''O^{26}$, which requires 10·4 per cent. barium.

JALAPIN. $C^{34}H^{56}O^{16}$. (J. Johnston, Phil. Trans. 1840, p. 342; Phil. Mag. [3], xvii. 183.—A. Kayser, Ann. Ch. Pharm. li. 101.—W. Mayer, *ibid.* xcv. 129.—*On Jalapin from scammony-resin:* Johnston, Phil. Trans. 1840, p. 340.—Fr. Keller, Ann. Ch. Pharm. civ. 63; further, with altered data, *ibid.* cix. 209.—Spirgatis, *ibid.* cxvi. 289.)

This substance (Kayser's *Pararhodeoretin*) occurs in the root-stalk of *Convolvulus* (or *Ipomœa*) *orizabensis*, the jalap-stalks or jalap-wood of commerce, and forms the principal portion (soluble in ether) of the jalap-resin prepared therefrom. [On the resin of tuberose jalap-root, see ii. 15.]

The resin of jalap-stalks has been examined also by Hänle (Repert. xlviii. 365), and Planche (J. Pharm. xxiv. 169). According to Weppen (N. Br. Arch. lxxxvii. 153), it resembles the resin of *Convolvulus arvensis*, which, like jalapin, assumes a fine purple-red colour with sulphuric acid, and is soluble in ether (contrary to the statement of Planche, J. Pharm. xiii. 165, who found it insoluble in ether). The same resin has been examined by Chevallier (J. Pharm. ix. 306). The resin of *Convolvulus Soldanella* appears, according to Planche, to be freely soluble in ether and alcohol, as also the portion of the tuberose jalap-root which is soluble in ether: both these resins are therefore, perhaps, jalapin.

Commercial scammony resin, from *Convolvulus Scammonia*, was described some years ago by Bouillon-Lagrange and Vogel; also by Planche (J. Pharm. xiii. 165; xviii. 183). Cl. Marquart (N. Br. Arch. vii. 248; x. 139) described the resin obtained from the root, and believed he had separated from it a vegetable base (*convolvuline*). Johnston recognised the similarity between scammony-resin and the resin of the jalap-stalks; Spirgatis showed that *scammonin*, the chief constituent of the former, is either identical with jalapin, or differs from it only in so far that, when decomposed by acids, it at once yields scammonolic (jalapinolic) acid; whereas jalapin, according to Mayer, when treated in a similar manner, yields at first jalapinol (p. 439). These statements are, perhaps, better founded than the contrary statements of Keller and Kosmann (p. 440.)

According to Planche, the resin of *Convolvulus sepium*, and according to Boutron and Charlard, that of *Conv. Turpethum* (J. Pharm. viii. 131), are not soluble in ether, and may thus be distinguished from jalapin.

In what follows, the statements of Kayser and Mayer relate to jalapin from jalap stalks; those of Keller and Spirgatis, to that from scammony.

Preparation.—a. From commercial *Resina Jalappæ ex stipitibus.* To a solution of the resin in a large quantity of alcohol, water is added, until it becomes slightly turbid; the whole is repeatedly boiled with animal charcoal, and the still-coloured filtrate is precipitated by neutral acetate of lead and a little ammonia, which produces a small greenish-brown precipitate. The liquid is filtered, and the filtrate freed from lead by passing sulphydric acid through it, then heating and filtering; the alcohol is again distilled off, and the resinous residue repeatedly kneaded in boiling water, then dissolved in ether, from which it may be recovered by evaporation (Mayer). Or the alcoholic resin, after treatment with animal charcoal, is boiled for a long time with freshly-precipitated hydrated oxide of lead; the lead is separated from the filtrate by sulphydric acid; and the resin is three times separated by water from the alcoholic solution, then

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led in water and dissolved in ether (Mayer). Kayser exhausts the root with ; evaporates the tincture; washes the resinous residue with hot water, dissolves cohol, and treats the solution with animal charcoal; distils off the alcohol; e residue again with water; and dries it over a water-bath. Johnston ex- a resin that was obtained either by dissolving the commercial resin in ether porating the solution; or by exhausting the ground root of commerce with hot evaporating the brown tincture, and extracting the residue with ether; or by ng chips of the root with cold alcohol, evaporating, boiling the residue in issolving the resinous residue in ether, and evaporating the solution.

om Scammony.—Coarsely-powdered scammony is exhausted with cold alcohol according to Keller); the tincture is diluted with water till it becomes turbid, sed by animal charcoal, and filtered; the greater part of the alcohol is dis- ; and the residue mixed with water is heated in a water-bath, till the whole lcohol is driven off, after which the resin is treated for a long time in a water- th frequently-renewed hot water, and at last dried up. The residue may be d in ether and recovered by evaporation. (Spirgatis.)

alapin (obtained according to *a* or *b*) still contains a small quantity of a volatile lerianic acid, according to Keller), which cannot be completely removed even long washing. It betrays itself by the smell which the jalapin emits when it rted by bases into jalapic acid, and the resulting solution supersaturated with l acid. Keller regards this acid, the bulk of which passes off in the water washing the jalapin, as an essential product of the decomposition of scammony; Mayer and Spirgatis regard it as a mere contamination.

rties.—Jalapin is a colourless, amorphous resin, translucent when in thin at 100° it becomes brittle, and may be rubbed down to a white powder. It 123°, and melts at 150° to a transparent, colourless, or pale-yellow syrup. It ss and inodorous; in alcoholic solution it gives a scarcely perceptible acid re Mayer, Spirgatis). It is but slightly soluble in *water*, but dissolves very nd without decomposition in *alcohol*, *wood-spirit*, *ether*, and *chloroform*. It also in *benzene*, *oil of turpentine*, and *petroleum*.

mposition of jalapin dried at 100°, or in a vacuum at common temperatures, by the following analyses.

	Calculation.		Analyses.			
			Kayser.	Mayer.	Keller.	Spirgatis.
C . .	408	56·66	58·13	56·52	56·65	56·47
H . .	56	7·77	8·07	8·18	8·39	7·93
O . .	256	35·57	33·80	35·30	34·96	35·60
$^{O^{16}}$	720	100·00	100·00	100·00	100·00	100·00

ton found in the resin obtained from jalap-stalks, 55·76 to 56·65 per cent., in ny-resin 54·06 to 55·32 per cent. carbon. Keller gives the formula $C^{36}H^{57}O^{25}$.

positions.—1. Jalapin *heated* above 127° gives off carbon and hydrogen in n of a volatile compound, which contains less oxygen than the residual resin ton). Jalapin which melts at 150°, becomes brown when further heated, and a pungent empyreumatic odour (Spirgatis).—2. When heated on platinum- kes fire, burns with a bright sooty flame and empyreumatic odour, and leaves .—3. It dissolves slowly in cold strong *sulphuric acid*, the solution, in five or tes, acquiring a beautiful purple or maroon-red colour, then becoming brown, lly black. On standing, or after dilution, a brown resin or a brown tallowy parates from the liquid, while sugar remains dissolved (Kayser, Mayer, tis).—4. By heating with dilute *mineral acids*, jalapin (even that which has solved in alkalis and thereby converted into jalapic acid) is decomposed into and sugar (Mayer). When jalapin from scammony is treated in the same apinolic acid is obtained in place of jalapinol (Spirgatis). Formation of :

$$2C^{34}H^{56}O^{16} + 11H^2O = C^{32}H^{62}O^{7} + 6C^6H^{12}O^6 \text{ (Mayer).}$$

inolic acid:

$$C^{34}H^{56}O^{16} + 5H^2O = C^{16}H^{30}O^{3} + 3C^6H^{12}O^6.$$

alapin (or pure jalapic acid) has been used, no other bodies are produced than st mentioned (Mayer, Spirgatis). According to Keller, when a solution or alcoholic?) of scammonin is treated with strong sulphuric acid or with oric acid gas, and then left to itself, three decomposition-products result, and ation of a fourth (formic acid or formic aldehyde) appears probable from the The products of this decomposition are—*a.* A *neutral body*, $C^{18}H^{30}O^{4}$, also e by alkalis into scammonolic acid (jalapinolic acid), and an alcohol, $C^{28}H^{28}O^{2}$.—

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b. Amylic aldehyde, which passes over as valerianic acid when scammony-resin is boiled with potash-ley, and then with dilute sulphuric acid.—*c.* A *carbo-hydrate*, $C^{12}H^{9}O^{9}$, which, however, is converted into sugar by simple boiling with dilute sulphuric acid. Keller gives the equation:

$$C^{76}H^{67}O^{35} = C^{28}H^{28}O^{4} + C^{10}H^{10}O^{2} + 3C^{12}H^{9}O^{9} + C^{2}H^{2}O^{2}.$$

But, according to Spirgatis, the neutral body *a* must be regarded as ethyl-scammonolic ether: moreover, the valerianic acid is obtained only from impure scammonin. Kosmann (J. Pharm. [3], xxxviii. 83), by boiling scammony-resin with dilute sulphuric acid, obtains sugar and his *scammoneol*, as a soft, yellowish-white substance, having a silky lustre and acid reaction, and separating from the hot alkaline solution on cooling. He calculates, according to Johnston's analysis of scammony-resin, the formula $C^{32}H^{52}O^{16}$ for scammonin, and so arrives at the equation of decomposition:

$$C^{32}H^{52}O^{16} + 5H^{2}O = 3C^{6}H^{12}O^{6} + C^{14}H^{26}O^{3}.$$

—*5.* When jalapin is dissolved in aqueous solutions of *caustic alkalis*, *ammonia*, or *baryta-water*, or in boiling *alkaline carbonates*, water is assimilated, and jalapic acid, soluble in water, is formed (Mayer, Spirgatis), probably thus:

$$C^{34}H^{56}O^{16} + 2H^{2}O = C^{34}H^{60}O^{18}.$$

Even the purest jalapin yields also traces of jalapinolic acid and a volatile acid, but no sugar (Mayer). When jalapin is melted with *hydrate of sodium*, hydrogen is given off, and jalapinolic and oxalic acids are formed (Mayer). Keller, by boiling scammonin with alcoholic potash, obtained dark flakes (on account of impurities in the scammonin, according to Spirgatis); and on subsequently adding water to the solution, the compound, $C^{26}H^{28}O^{2}$ or $C^{13}H^{28}O$, was precipitated in white flakes, while valerate of potassium remained in solution. The body, $C^{13}H^{28}O$, regarded by Keller as an alcohol, is likewise formed, on boiling commercial jalapin (obtained from the resin of jalap-stalks) or scammony with baryta-water, or solution of potash; it evaporates with the water, and separates in gelatinous flakes from the distillate. At 40° it melts to an oil, crystallises on cooling, and contains, on the average, 78 per cent. C, 14·12 H, and 7·88 O. Keller regards this body as a product of the decomposition of scammonin (or more exactly of the neutral body, $C^{28}H^{28}O^{4}$ or $C^{14}H^{28}O^{2}$; Spirgatis regards it as a mixture of resins, since the greater portion of it is obtained on distilling the impure resin with water.

6. By *nitric acid*, jalapin is at first decomposed into jalapinol and sugar, and these products, when further subjected to the action of the nitric acid, are converted into ipomæic and oxalic acids (Mayer). A small quantity of nitric acid does not colour jalapin; but, in presence of guaiac-resin, a green colour is produced (Bull, Spirgatis). —7. When *sulphurous anhydride* is passed through an ammoniacal alcoholic solution of scammony resin, silvery-shining plates are separated, containing perhaps an aldehyde in combination with acid sulphite of ammonium. (Keller.)

JALAPINOL. $C^{32}H^{62}O^{7}$. (W. Mayer, Ann. Ch. Pharm. xcv. 145.)—Jalapin and jalapic acid are resolved, by contact with mineral acids, slowly at ordinary, more quickly at elevated temperatures, into jalapinol and sugar (pp. 437, 439). Jalapinol and sugar were also produced, in one instance, when aqueous jalapic acid was left for 24 hours in contact with emulsion of almonds at 36° to 38°; whereas, in a second experiment, pure emulsin did not effect the decomposition, perhaps because the solution was too strongly heated.

To prepare jalapinol, a moderately concentrated aqueous solution of jalapic acid is mixed with half its bulk of fuming hydrochloric acid, and left to itself for days, or till the clear mixture has solidified to a thick crystalline pulp; and the product, after being washed on a filter with cold water, is repeatedly melted under warm water, and purified by recrystallisation from alcohol, with help of animal charcoal.

Jalapinol forms white, cauliflower-like crystals, which melt at 62° or 62·5°, and solidify at 59·5° to a hard, brittle, crystalline mass. It makes grease-spots on paper; is inodorous; has an irritating taste, and weak acid reaction. It is soluble in *alcohol* and in *ether*.

In contact with *caustic alkalis*, aqueous *ammonia*, or *baryta*, it is converted, with elimination of water, into a salt of jalapinolic acid:

$$C^{32}H^{62}O^{7} + 2BaHO = 2C^{16}H^{29}BaO^{3} + 3H^{2}O.$$

JALAPINOLIC ACID. $C^{16}H^{30}O^{3}$.—An acid produced—1. By treating jalapinol with caustic alkalis, or with baryta (Mayer).—2. By the action of melting hydrate of potassium on jalapin or jalapic acid (Mayer). Jalapin and jalapic acid, prepared from scammony, are resolved by mineral acids into jalapinolic acid and sugar. (Spirgatis.)

Preparation.—1. Jalapin is added gradually and by small portions to hydrate of

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melted with $\frac{1}{8}$th pt. of water (the mass then frothing up violently, giving off
gen and turning brown); the mixture is heated and stirred as long as hydrogen
ues to escape; the crumbling light-yellow mass is dissolved in water after cool-
nd the greater part of the alkali is neutralised with acid. The jalapinolate of
, which separates after some hours, is collected, washed, and decomposed by
cidulated water; the separated acid is again repeatedly melted with pure
then dissolved in alcohol and treated with animal charcoal; the somewhat
trated filtrate is mixed with a large quantity of warm water; and the solid acid
separates on cooling is collected (Mayer). From the mother-liquor filtered
he jalapinolate of sodium, excess of acid still separates a small quantity of im-
alapinolic acid (Mayer).—2. The hot aqueous solution of jalapic acid (from
ony) is digested in the water-bath for a fortnight with dilute sulphuric acid;
he tallowy mass which separates on cooling, is freed from sulphuric acid by
g with hot water, and crystallised from ether with help of animal charcoal
gatis).—3. Jalapin from scammony is added to boiling baryta-water; the
is heated till the whole is dissolved, and a sample of the filtrate is not rendered
either by water or by hydrochloric acid; and the solution, after filtration, is
with one-third of its volume of fuming hydrochloric acid. The liquid becomes
in about 20 hours, and solidifies in the course of 10 days to a thick pulp, which
ected, washed with cold water, remelted with hot water, and recrystallised four
times from aqueous alcohol.

perties. Jalapinolic acid forms white tufts of needles, appearing under a magni-
power of 300, as thin 4-sided prisms. It melts at 64° or 64·5° (60° to 61°,
ing to Keller,) and solidifies at 61·5° or 62° (Mayer), at 50° (Spirgatis),
hite radio-crystalline, hard and brittle mass. It makes grease-spots on paper;
ter than water; inodorous, but has an irritating taste and acid reaction (Mayer,
gatis). It is insoluble in *water*, but soluble in *alcohol* and in *ether*.
en *heated* above its melting point, it decomposes with intumescence, emitting a
nt odour which attacks the eyes and throat.—*Nitric acid* oxidises it to ipomæic
nd oxalic acid (Mayer, Spirgatis).

apinolates. The acid is monobasic, the general formula of its neutral salts
$C^{16}H^{29}MO^3$.

pinolate of Ammonium, $C^{16}H^{29}(NH^4)O^3.C^{16}H^{30}O^3$.—By dissolving jalapinol or
olic acid in aqueous ammonia, an opalescent liquid is obtained which gives off
nia when evaporated, solidifies to a crystalline mass when concentrated to a
point, but if completely evaporated, leaves an amorphous neutral jelly soluble
er. The crystals are grouped like cauliflower-heads, and when strongly magni-
ppear as long colourless needles. (Mayer.)

pinolate of Barium, $C^{32}H^{58}Ba''O^6$, is obtained by precipitating jalapinolate of
nium with chloride of barium, or by boiling jalapinol or alcoholic jalapinolic
ith baryta, and crystallises out on cooling, in microscopic, thin, white, lustreless
s, melting to a colourless liquid when heated. It is nearly insoluble in cold,
gly soluble in boiling water, more easily in boiling aqueous alcohol. (Mayer,
gatis.)

pinolate of ammonium precipitates aqueous *chloride of calcium*.

pinolate of Copper. a. *Basic.*—When a slightly alkaline aqueous solution of
monium-salt is precipitated with cupric acetate, and the precipitate is washed
ied at 100°, a dark blue-green, amorphous, very loose mass is obtained, which
without loss of water, to a dark green liquid, and solidifies to a translucent
mass. It is insoluble in water, nearly soluble in alcohol, contains at 100°,
per cent. cupric oxide, and is therefore $2C^{32}H^{58}Cu''O^6.Cu''H^2O^2$ (calc. 18·24 per
CuO). (Mayer.)

Neutral.—$C^{32}H^{58}Cu''O^6$. A hot aqueous solution of jalapinolate of sodium forms
ot aqueous cupric sulphate, a green-blue precipitate, which dries up to a light
reen amorphous powder, melting to a dark green liquid when heated. (Spirgatis.)
e by analysis 13·24 per cent. CuO, the formula requiring 13·28 per cent.

pinolate of ammonium precipitates *iron-salts*.

pinolate of Lead, $C^{32}H^{58}Pb''O^6$, is obtained by precipitating alcoholic jalapinolic
ixed with a little ammonia, with neutral acetate of lead, and washing the white
hous precipitate with dilute alcohol and water. It sinters together to an opaque
t 120°. It is sparingly soluble in water and alcohol.

pinolate of Potassium is obtained by dissolving jalapinol in boiling aqueous
. The solution on cooling solidifies to a crystalline pulp, which, after washing,
crystallisation from water or alcohol, forms slender, white, silky needles, melting
t decomposition when heated. It is neutral, forms an opalescent solution with
even when free alkali is present, and is soluble in alcohol.

pinolate of Silver, $C^{16}H^{29}AgO^3$.—The alcoholic solution of the acid neutralised

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with ammonia is precipitated by a warm solution of nitrate of silve have a scarcely perceptible crystalline character. (Keller.)

Jalapinolate of Sodium, $C^{16}H^{29}NaO^4$, crystallises in slender da of needles, which form a turbid solution with a small quantity of neutral solution with a larger quantity, and are likewise soluble in alcoh

Jalapinolic Ether, $C^{18}H^{34}O^3 = C^{16}H^{29}(C^2H^5)O^4$. *Scammon* hydrochloric acid gas is passed into a solution of jalapinolic acid in and the resulting liquid is mixed with water, a yellow oil separat washed, after solidification, with cold alcohol, dissolved in boiling al carbonate of sodium, and after it has separated out on cooling, repea from the alcoholic solution by water. It may also be obtained from by passing hydrochloric acid gas into the alcoholic solution. (Spirg

JALPAITE. A cupriferous silver-glance from Jalpa in Me blackish lead-grey colour, is malleable like ordinary silver-glance, a gravity of 6·877 to 6·890. According to an analysis by R. Ri 14·36 per cent. sulphur, 71·51 silver, 13·12 copper, and 0·79 iron, agr the formula, $\frac{3}{4}Ag_2 \atop \frac{1}{8}Cu''$ ^2S. (Breithaupt, Jahresber. 1858, p. 682.)

JAMAÏCINE. An alkaloïd said to be contained in the bark of a leguminous tree growing in Jamaica and in Surinam. (Hüttens Mag. Pharm. Sept. 1824.—Winckler, Pharm. Centr. 1840, p. 120.

JAMESONITE. A sulphantimonite of lead occurring in ∞P : ∞P = 101° 20′ and 78° 40′. Observed planes ∞P, ∞P∞. very distinct; parallel to ∞P and ∞P∞ less distinct. Sometimes capill with columnar structure; particles delicate, straight and parallel or d ness = 2 to 2·5. Specific gravity = 5·5 to 5·8 (Haidinger). Colour and streak steel-grey. Opaque. Sectile.

When heated in an open tube, it gives off dense white fumes of an on charcoal before the blowpipe it decrepitates, fuses readily, and wholly in fumes.

Analyses.—*a.* from Cornwall, mean of three analyses by H. Rose 99).—*b.* from Estremadura, by Schaffgotsch (*ibid.* xxxviii. 403).— by Bechi (Sill. Am. J. [2] xiv. 60).—*d.* from Arany, Idka, by L *Berichte*, i. 62).

	S	Sb	Bi	Pb	Fe	Cu	Zn
a.	22·34	34·29	. .	39·94	2·64	0·18	trace
b.	21·78	32·62	1·05	39·97	3·63	. .	0·42
c.	20·53	32·16	. .	43·38	0·94	1·25	1·74
d.	18·59	33·10	0·22	40·82	2·99	1·78	0·35

These analyses lead to the conclusion that Jamesonite is an isomor sulphantimonite of lead $2PbS.Sb^2S^3$, with the corresponding compound zinc, and silver). Such a mixture of one molecule of the iron-salt an of the lead-salt, viz. $2FeS.Sb^2S^3.3(2PbS.Sb^2S^3)$ or $(FePb^3Sb^6)^{\cdots}S^{16}$, wou per cent. S, 32·55 Sb, 42·02 Pb, and 3·79 Fe.

Jamesonite occurs principally in Cornwall, associated with quartz an of bournonite; occasionally also in Siberia, Hungary, Spain, and Brazi Rammelsberg, p. 68).

JAPONIC ACID. $C^{12}H^{10}O^4$.—An acid produced by exposing tion of catechin in caustic potash. The liquid slowly blackens, and chloric acid, a black precipitate of japonic acid is produced. The a water, but insoluble in alcohol. It forms with potash, a black sal black precipitates with metallic solutions. (Svanberg, Ann. Ch. P

JARGIONITE. A variety of galena, crystallised in octahedrons. 6·932.

JARGON. Syn. with Zircon.

JAROSITE. A native ferroso-potassic sulphate from Baranco J Amagrera in Spain. Crystallises in yellowish rhombohedrons wit (Dana, ii. 389.)

JASPER. A sub-species of quartz of which the following vari rated by Jameson.

1. *Egyptian jasper*, which is red or brown. The first is flesh-red, and brown, in ring-shaped delineations; in roundish pieces, dull, wit ture. Feebly translucent on the edges. Hard; easily frangible. Spec It is found imbedded in red clay-ironstone at Baden, and is cut into o

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The *brown* variety has its various shades of colour disposed in concentric stripes, ternating with black stripes. It occurs in the sands of Egypt, in spheroïdal masses, ith glimmering lustre. Fracture conchoïdal. Feebly translucent on the edges. As rd as horn-stone. Specific gravity 2·6. Infusible. It is cut into ornaments.

2. *Striped jasper*. Colours grey, green, yellow, red, arranged in stripes, in flamed spotted delineations. Massive, in whole beds. Dull. Fracture conchoïdal. Opaque. ess hard than Egyptian jasper; rather easily frangible. Specific gravity 2·5. It curs in secondary clay-porphyry in the Pentland hills, and near Friburg in Saxony. receives a fine polish.

3. *Porcelain jasper*. Colours grey, blue, yellow, generally of one colour, or with ouded delineations. Massive, and cracked in all directions. Lustre glistening. Frac- re conchoïdal. Opaque. Easily frangible, and not very hard. Specific gravity, 2·5, ses into a white or grey glass. It is always found along with burnt clay and earth ags. According to Werner, it is slate-clay converted into a kind of porcelain, by the eat of a pseudo-volcano from beds of burning coal. It is found on the coast of Fife- ire, in Shropshire, and Warwickshire, and some parts of Germany, where immense eds of coal appear.

4. *Common jasper*. Colours red and brown. Massive. Lustre, from shining to dull. racture conchoïdal. Opaque. Hard in a low degree; rather easily frangible. Specific ravity 2·6. Infusible before the blowpipe, becoming at last white. It occurs princi- ally in veins as a constituent of agate. It is found in the Pentland hills, and in trap nd transition rocks in Ayrshire and Dumfriesshire.

5. *Agate jasper*. Colours yellowish- and reddish-white. Massive, dull. Fracture at, conchoïdal. Opaque. Rather hard. It occurs in layers in agate-balls in many laces. U.

The *iaspis* of the ancients, whence our word jasper is derived, appears to have in- luded the green or blue variety, together with some other stones not of the jasper ind.

JATROPHA. A genus of euphorbiaceous plants, some of which contain in- ensely poisonous juices: the seeds of several species yield fixed oil.

The kernels of the seeds of *Jatropha Curcas* were found by Arnaudon and Ubal- ini (Cimento, vii. 431) to contain 7·2 per cent. water, 37·5 oil, 55·3 sugar, starch, lbumin, casein and inorganic matters. The kernels yielded 4·8 per cent. ash, and ·2 per cent. nitrogen; the kernels and husks together, 6 per cent. ash and 2·9 per cent. itrogen. The oil yielded by saponification, glycerin, and an acid which, as well as he unsaponified oil, produced octylic alcohol by distillation with hydrate of potas- ium.

The oil of the fruit of *Jatropha glauca* and of *J. glandulosa* is yellow, has a specific ravity of 0·963 and solidifies at 5°. (J. Lepine, J. Pharm. [3] xl. 16.)

The root of *Jatropha Manihot* contains a large quantity of starch, which when freed rom the poisonous juice of the plant by washing and torrefaction, constitutes Brazilian rrow-root (i. 359.)

JEFFERSONITE. A dark-green, crystallised, foliated variety of augite, con- aining zinc, from Mine Hill, Franklin, New Jersey. Specific gravity 3·6. Formula Ca; Fe; Mg; Zn)$^{\prime\prime}SiO^3$.

JELLETITE. An altered form of garnet, said to occur in rhombic prisms with ngles of 60°, the supplement of which, 120°, is the angle of the rhombic dodecahedron. pecific gravity = 3·741. Hardness above 7. Occurs as a yellowish, slightly greenish ncrustation, and is compact in its texture. Composition, according to Wright J. Geol. Soc. Dublin, v. 119), 38·09 SiO^2, 33·41 Fe^2O^3, 28·61 CaO = (100·11), which f a small part of the iron is regarded as protoxide, gives the formula of garnet. Dana, ii. 194.)

JEFREINOFFITE or **JEWREINOWITE.** A variety of vesuvian from Finland, containing, according to Ivanhoff, 37·41 SiO^2, 34·20 CaO, 20·00 Al^2O^3, 4·60 FeO, 1·16 K^2O, and 1·70 Na^2O (= 99·07). It is usually yellowish-brown, but some- imes colourless. (Dana, ii. 506.)

JENKINSITE. Syn. with Hydrophite (p. 212).

JERVINE. An alkaloïd discovered by E. Simon (Pogg. Ann. xli. 569), in the oot of white hellebore (*Veratrum album*), in which it exists, together with veratrine. t is extracted by mixing the alcoholic extract of the root with dilute hydrochloric cid and precipitating with carbonate of sodium. The precipitate is dissolved in lcohol, the solution decolorised with charcoal, and the alcohol removed by distillation. The greater part of the residue then solidifies in a crystalline mass, from which the eratrine, being uncrystallisable, may be almost entirely removed by submitting it to ressure, moistening the resulting cake with alcohol, and pressing again. In this

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manner jervine is obtained nearly pure. A further quantity may be form of sulphate, by evaporating to dryness the expressed liquid, wh jervine and veratrine, and treating the residue with dilute sulphuric up sulphate of veratrine, and leaves sulphate of jervine.

Jervine is colourless and crystalline; gives off 6·9 per cent. water (2 at.) at 100°, and melts at a higher temperature to a colourless poses when heated above 200°. It is insoluble in water, soluble sparingly soluble in ammonia.

According to Will's analysis (Ann. Ch. Pharm. xxxv. 116), it 74·55 per cent. carbon, 9·57—9·74 hydrogen, and 5·38 nitrogen, whe the formula $C^{30}H^{45}N^{2}O^{3}$ for which Gerhardt substituted $C^{26}H^{41}N^{2}$ (calculation 74·7 per cent. C, 9·5 H, 5·7 N, and 10·1 O).

Jervine gives off ammonia when fused with *potash*.

Acetate of jervine is soluble in water. The *sulphate*, *nitrate*, and very sparingly soluble in water and in mineral acids. The *chloropla* yellow flakes which give by analysis 14·55—14·33 per cent. platin $2(C^{30}H^{46}N^{2}O^{3}.HCl).PtCl^{4}$ requiring 14·3 per cent.

JET. A variety of bituminous coal, resembling cannel coal, but a stronger lustre. Specific gravity 1·3. It occurs, together with li floetz, trap, and limestone rocks, and in bituminous shale. It is fou Whitby, in Yorkshire, in the Isles of Skye and Faroe, in Hessia, H and Styria. It is used for fuel and for making various ornamental a

It is the *Gagates* of Dioscorides and Pliny, a name derived from th Syria, near the mouth of which it was found.

JEWREINOWITE. Syn. with Jefreinoffite.

JOHANNITE. Native uranous sulphate. See Uranium.

JOHNITE. Syn. with Turquois.

JUGLANDIN. A substance contained in the juice expressed fr of the walnut (*Juglans regia*). The fresh juice is nearly limpid, h taste, turns brown rapidly in contact with the air, and then loses its prolonged contact with the air, it deposits brown tasteless flocks, i and alcohol, the juice at the same time losing its bitterness. The fr iron-salts; the browned juice, when mixed with potash, precipitates losing its colour at the same time. With nitrate of silver it fo which blackens rapidly, and contains metallic silver.

The extract of green walnut-shells consists of impure juglandin. remedy in cutaneous and scrophulous diseases, also for dyeing the ha *Traité*, iv. 307).

JUNIPER. The berries of the juniper (*Juniperus communis*), w flavouring gin, and in the form of aqueous decoction, also in medi contain, according to Trommsdorff, 1·0 per cent. essential oil of juni resin, 33·8 sugar, together with acetate and malate of calcium, 7·0 g salts, 35·0 woody fibre, and 12·9 water.

The *essential oil of juniper*, obtained by distilling the berries wi composition and vapour-density of oil of turpentine ($C^{10}H^{16}$); boils a plane of polarisation to the left, but less strongly than oil of turpe little soluble in alcohol of ordinary strength. It does not form a sol hydrochloric acid; but after the complete absorption of the gas, a which appears to contain $3C^{10}H^{16}.2HCl$.

The old and moist essence deposits crystals which appear to be iden of turpentine. It is acid and contains formic acid.

By distilling unripe juniper-berries with salt-water, Blanchet obta which boiled at 205°, but appeared to have the same composition as t (*Gerh. Traité*, iii. 637.)

JUNKERITE. Spathic iron ore.

JURINITE. Syn. with Brookite.

K

KÆMMERERITE. A variety of pyrosclerite containing a con of chromium. (See Pyrosclerite.)

KÆMPFERIDE. A substance contained in the root of *Kæ* It may be extracted by ether, together with a brown, viscid, aromati

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removed by dissolving the product several times in alcohol, the brown sub-
eparating first when the solution is left to evaporate.
pferide crystallises in yellowish nacreous laminæ, without taste or smell. It
t a temperature above 100°, dissolves in 25 pts. of ether at 15°, is less
n alcohol, and nearly insoluble in water. It dissolves in warm acetic acid,
solution yields with ammonia a precipitate soluble in excess of that reagent.
ic acid imparts to it a fine bluish-green colour. Caustic potash dissolves it
low colour; carbonate of potassium with effervescence.
pferide gave by analysis (calculated with the old atomic weight of carbon)
cent. C, 4·3 H and 30·4 O. (Brandes, Ann. Ch. Pharm. xxxii. 312.)

ISACCHARIC ACID. Syn. with GLUCIC ACID (ii. 848.)

YPLOTITE. A name given by Shepard (Sill. Am. J. [2], xii. 210) to
nall black-brown crystals from Haddam, Connecticut, regarded by him as a
eral. Dana, however, regards them as garnets.

IALA. A substance obtained from the fruit of *Rottleria tinctoria*, and used
thelmintic (see ROTTLERIA).

EITE. Arsenical Manganese. (See MANGANESE.)

LIN. The Chinese name of porcelain clay (i. 1024).

NITE. A variety of calamine containing more than 15 per cent. of ferrous
The angle of the rhombohedron R : R is 107° 7 (Breithaupt).

ELINITE. An oxysulphide of bismuth occurring, together with telluric
the Sawodinsk mine in the Altaï. It forms crude lumps, having a metallic
decidedly crystalline fracture, with prevailing cleavage in one direction, strong
lustre on the fractured surface, and lead-grey colour. Hardness = 2; specific
= 6·60. On treating the pulverised mineral with hydrochloric acid, a small
of admixed bismutite (i. 597) dissolves and pure karelinite remains undissolved.
er heated in a test-tube gives off sulphurous anhydride, but no free sulphur,
s a grey slag, from which globules of metallic bismuth ooze out; heated in an
be, it also gives off sulphurous anhydride, and leaves a metallic regulus sur-
by a brown easily fusible oxide. Nitric acid easily decomposes the mineral,
paration of sulphur. The mineral gives by analysis 91·26 per cent. bismuth,
phur, and 5·21 oxygen, agreeing with the formula Bi^4SO^3 or $Bi^2S.Bi^2O^2$.
rmann, J. pr. Chem. lxxv. 448.)

RPHOLITE. See CARPHOLITE (i. 806).

RPHOSIDERITE. See CARPHOSIDERITE (i. 807).

STENITE. Syn. with ANHYDRITE (i. 295).

VA-ROOT. The root of *Piper methysticum* (Forster). When dried be-
10° and 120°, it leaves a residue amounting to 85 per cent.: after exhaustion
ohol and with water, it leaves 75 per cent. of residue containing 26 pts. woody
d 49 starch. By exhausting the root with alcohol of 80 per cent. an extract
a peculiar smell and taste is obtained, the solution of which in warm alcohol
needle-shaped crystals, while a resin remains dissolved.
crystalline substance called methysticin, forms, when purified by repeated
sation, small white silky needles, destitute of taste and smell. It is insoluble
, sparingly soluble in cold alcohol and ether; reacts neutral; melts at 130°, and
ses at a stronger heat; is dissolved by nitric acid with orange-yellow colour,
sulphuric acid with violet colour. It yields by analysis 62·03 per cent carbon,
drogen, and 1·12 nitrogen.
resin kawin, contained, together with myristicin, in the alcoholic extract of
t, is a soft greenish-yellow substance, which has a strong aromatic taste and
melts at 50°, decomposes at a stronger heat, and produces a deep red colour
lphuric acid. 100 pts. of kawa-root contain 15 pts. water, 26 woody fibre,
ch, 1 methysticin, 2 acrid aromatic resin, 3 extractive and gummy matter,
de of potassium, and 3 magnesia, silica, alumina, and ferric oxide. (Gobley.
m. [3], xxxvii. 19.—O'Rorke, Compt. rend. l. 498.)

VAIN. A crystallisable non-azotised substance, from kawa-root; it contain
er cent. carbon and 5·64 hydrogen. (Cuzert, Compt. rend. l. 436; lii. 206.)

WIN. The resin of kawa-root. (See above.)

ORIA TERRESTRIS. Barbadoes tar. (See BITUMEN.)

LHAUITE. Syn. with YTTROTITANITE.

LP. Incinerated sea-weed. (See SEA-WEED.)

RAMOHALITE. A hydrated sulphate of aluminum from near Königsberg

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in Hungary, having the same composition as alunogen (i. 161). It occurs in crystalline crusts, and six-sided tables of the monoclinic system, with two angles of 92°, and four of 134°. Specific gravity = 1·6 to 1·7. Contains 14·30 per cent. alumina, 2·15 ferrous oxide, 36·75 sulphuric anhydride, 44·60 water, and 2·01 insoluble matter (= 99·81), agreeing approximately with the formula $Al^2(SO^4)^3.18H^2O$.

KERAPHYLLITE. Syn. with CARINTHIN (i. 804).

KERARGYRITE or *Horn-silver*. Native chloride of silver (See SILVER).

KERASITE, *Cerasine*, or *Horn-lead*. A native compound of chloride and carbonate of lead. (See LEAD.)

KERATE. Syn. with KERARGYRITE.

KERMES (*Coccus ilicis*, Lin.) is an insect found in many parts of Asia, and the south of Europe. On account of their figure, these insects were a long time taken for the seeds of the tree on which they live: whence they were called *grains of kermes*. They also bore the name of vermillion.

To dye spun worsted with kermes, it is first boiled for half an hour in water with bran, then for two hours in a fresh bath with one-fifth of Roman alum and one-tenth of tartar, to which *sour water* is commonly added; after which it is taken out, tied up in a linen bag, and carried to a cool place, where it is left some days. To obtain a full colour, as much kermes as equals three-fourths, or even the whole of the weight of the wool, is put into a warm bath, and the wool is put in at the first boiling. As cloth is more dense than wool, either spun or in the fleece, it requires one-fourth less of the salts in the boiling, and of kermes in the bath.

The colour that kermes imparts to wool has much less bloom than the scarlet made with cochineal; whence the latter has generally been preferred, since the art of heightening its colour by means of solution of tin has been known. U.

KERMES, MINERAL. Amorphous trisulphide of antimony. (See ANTIMONY, SULPHIDES OF, i. 330.)

KERMESITE or **KERMESOME.** *Red Antimony. Antimony-blende. Pyrantimonite. Pyrostilbite. Rothspiessglanzerz.*—A native oxysulphide of antimony, occurring in monoclinic crystals, cleaving parallel to the base; usually in tufts of capillary crystals, consisting of elongated, slender, six-sided prisms. Hardness = 1 to 1·5. Specific gravity = 4·5 to 4·6. Lustre, adamantine, inclining to metallic. Colour, cherry-red. Streak, brownish-red. Feebly translucent. Sectile. Thin leaves slightly flexible. Contains 74·45—75·66 antimony, 5·29—4·27 oxygen, and 20·49 sulphur (H. Rose, Pogg. Ann. iii. 453), answering to the formula Sb^2OS^2 or $Sb^2O^3.2Sb^2S^3$. Before the blow-pipe on charcoal, it fuses readily, and is at last entirely volatilised. In nitric acid it becomes covered with a white coating.

This mineral, which results from the alteration of native sulphide of antimony, occurs in veins in quartz, accompanying grey and white antimony, at Malaekza near Posing in Hungary, at Bräunsdoff near Freiberg in Saxony, and at Allemont in Dauphiné. (Dana, ii. 141.)

KEROLITE. See CEROLITE (i. 836).

KETONES. See ACETONES (i. 31).

KHAYA. The bark of the *Caïl-cedra* (*Khaya senegalensis* or *Swietenia senegalensis*), used in Senegal as a remedy against fever, contains a bitter principle, cailcedrin, together with green fat, red and yellow colouring matter, gum, starch, a waxy substance, woody fibre, sulphate and phosphate of calcium, and chloride of potassium. Caïl-cedrin, which may be extracted from the concentrated aqueous extract of the bark by chloroform, is a resinous mass containing 64·9 per cent. carbon, 7·6 hydrogen, and 27·5 oxygen. (Caventou, J. Pharm. [3] xvi. 355; xxxiii. 123.)

KIBDELOPHANE or *Axotomous Iron ore.* A variety of titaniferous iron, occurring sometimes in crystals, but usually massive, or in thin plates or laminæ. R : R = 85° 19′. Hardness = 5 to 5·5. Specific gravity = 4·661 (Mohs); 4·723 to 4·735. (Breithaupt.)

KIFFEKILL. See MEERSCHAUM.

KIESERITE. A name applied by Reichardt (Arch. Pharm. [2], ciii. 346) to a sulphate of magnesium, occurring in the shaft of the Stassfurth salt-mine near Magdeburg, and containing, according to his analysis, 21·66 per cent. MgO, 43·05 SO^3, and 34·56 water (= 99·27), agreeing approximately with the formula $2MgSO^4.3H^2O$.—Siewert (Zeitschr. f. d. ges. Naturw. xvii. 49) found in a much harder opaque specimen (mean) 28·56 MgO, 58·94 SO^3, and 13·47 H^2O), together with from 0·26 to 0·66 of matter insoluble in nitric acid), answering to the formula $2MgSO^4.H^2O$. Similar results were obtained by B. Leopold (*ibid.* p. 51), who also

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at the salt contained from 0·5 to 1·2 per cent. of an insoluble borate (see s); also previously by Rammelsberg (*Mineralchemie*, p. 264).

RICKENITE. Geocronite from Kilbricken, Clare County, Ireland. (See ITE, ii. 831.)

AS. The Cornish miners' name for clay-slate.

INITE. A mineral having the appearance of spodumene, found at Kil-, near Dublin. According to Mallet, it affords by cleavage a prism of 135°, very nearly the angle between the diagonal and prismatic cleavages of spo- both of which are perfect. Hardness = 4. Specific gravity = 2·56. Lustre, weak. Colour, greenish-grey, brownish, or yellowish. It has been analysed nt, Blythe, Mallet, and Galbraith (Dana, ii. 170; Rammelsberg's *hemie*, p. 837.)

Al^2O^3	FeO	CaO	MgO	MnO	K^2O	Li^2O	H^2O		
30·60	2·27	0·68	1·08	—	6·72	—	10·00	= 100·43	Lehunt.
31·64	2·33	0·72	0·46	1·25	6·06	—	10·00	= 99·80	Blythe.
33·24	3·27	1·45	—	—	4·94	0·46 Na^2O	3·67	= 99·92	Mallet.
30·13	3·53	—	1·09	—	4·81	0·95 Li^2O	7·58	= 98·54	Galbraith.
29·37	2·23	0·34	1·03	—	6·71	0·60	8·03	= 98·42	„

ing to Rammelsberg, this mineral, and likewise pinite, gieseckite, gigan- rite, and liebenerite, which are of somewhat similar constitution, are not ompounds, but products of decomposition intermediate between an original nd mica, which often adheres to and partly penetrates their mass.

C ACID. Syn. with QUINIC ACID.

. This name is applied to four different drugs, bearing considerable resem- catechu, and consisting of dry brown lumps or grains, having a more or less t taste. Their aqueous extracts form green precipitates with ferric salts. varieties of kino are African kino, also called *Gummi gambiense*, or *ia*, from the *Pterocarpus erinaceus* (Lam.); Asiatic kino, from *Pterocarpus m*; New Holland kino, from *Eucalyptus resinifera* (white); and American n *Coccoloba uvifera* (L.).

ing to Vauquelin, African kino consists of 75 pts. tannin and peculiar ex- natter, 24 pts. red gum, and 1 pt. fibrin.

s used in medicine as an astringent like catechu. (Handw. d. Chem. iv. 352.)

ONE. Syn. with QUINONE.

OVOUS ACID. $C^{24}H^{28}O^5$ (?). An acid obtained, together with several ducts, from the needles of *Pinus sylvestris*. (For the mode of preparation, see INS.) It is a white or slightly yellow brittle mass, converted by trituration ongly electric powder. The silver-salt contains 74·1 per cent. oxide of silver nearly with the formula $5Ag^2O.C^{24}H^{28}O^5$. (Kawalier, Wien. Akad. Ber.

IGITE. A name applied by H. Fischer to the mixture of red garnet, mica, elinic felspar (oligoclase), which occurs in veins in primitive gneiss rocks, Vittichen in the Kinzigthal, Scharzwald, at Auerbach in the Bergstrasse, and alities, and is regarded by him as an original formation. (Jahrb. Min., 1860, 861, p. 641.)

A fossil resin, found, with others, on the island of Tschelekän, in the Caspian in other neighbouring localities.

VANITE. A hydrated silicate of aluminium, calcium, and iron, occurring in the Mourne Mountain on the north-east coast of Ireland, in opaque, olive- diating fibres, having a specific gravity = 2·941 and hardness = 2. According alysis by R. D. Thomson, it contains 40·5 per cent. silica, 23·91 ferrous oxide, ne, 11·41 alumina, and 4·35 water (= 99·95), whence Rammelsberg deduces ula: $2[3(CaO.FeO).2SiO^2].Al^2O^3.2SiO^2.2H^2O$; it is possible, however, that part n may be in the state of ferric oxide.

ineral blackens and fuses partially before the blow-pipe, and forms a brown h soda or borax.

PROTHIN. Syn. with LAZULITE.

OCLASE. Syn. with ABICHITE.

BELITE. A mineral of unknown locality, closely related in composition to t differing from it considerably in its properties. According to Döbereiner's (Schw. J. xxi. 49), it contains about 32·5 per cent. silica, 32·0 ferrous oxide, manganous oxide, agreeing nearly with the formula $(Mn'' ; Fe'')^3SiO^4$, or

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$2(MnO; FeO).SiO^2$.—It is massive, with an uneven and cellular surface, and quite hard. Specific gravity, 3·714. Brittle, with imperfectly conchoïdal fracture. Colour, white to greyish-green, or brown-red and brown. Lustre glistening.

KOBELLITE. A mineral found in the cobalt mine of Hvena in Sweden. It consists, according to Setterberg's analysis (*Berzelius Jahresber.* xx. 215), of 17·86 sulphur, 9·24 antimony, 27·05 bismuth, 40·12 lead, 2·96 iron, 0·80 copper, and 1·45 matrix (=99·48), numbers which may be approximately represented by the formula: $2\left[\begin{matrix}Pb^3\\Sb^2\end{matrix}\right\}S^6] \cdot 3\left[\begin{matrix}Pb^3\\Bi^2\end{matrix}\right\}S^6]$, or $(Pb^{15}Sb^4Bi^6)S^{30}$, the lead being partly replaced by iron and copper. It resembles grey antimony, but has a brighter lustre and radiated structure. Specific gravity, 6·29—6·32. Soft; of blackish lead-grey to steel-grey colour, with black streak. Dissolves in strong hydrochloric acid, with evolution of sulphydric acid. (Dana, ii. 82; Rammelsberg, *Mineralchemie*, p. 106.)

KOENIGITE. Syn. with Brochantite (i. 664).

KOENLITE. A fossil resin resembling scheererite, found in brown coal at Uznach, at Redwitz in Bavaria, and in the Fichtelgebirge. It contains, according to Schrötter's analysis (Pogg. Ann. lix. 37), 92·43 per cent. C, and 7·71 H, agreeing with the formula nCH. It occurs in soft white crystalline folia and grains, of specific gravity 0·88; melts at 114° (Kraus, Pogg. Ann. xliii. 141), at 107·5° (Trommsdorff, Ann. Ch. Pharm. xxi. 126). Very slightly soluble in cold alcohol, more so in hot alcohol, still more in ether.

KOENLINITE. A fossil resin from the brown coal of Fassa, in the Eger Valley. It occurs in thin plates, consisting of an aggregate of crystalline scales, perfectly soluble in alcohol and ether, also in strong sulphuric acid; partly soluble in ammonia and in oil of turpentine. (Kenngott, *Mineralogische Untersuchungen*, ii. 111.)

KOETTIGITE. Native arsenate of zinc, $Zn''(AsO^3)^2.8H^2O$, or $ZnO.As^2O^5.8H^2O$, containing also nickel and cobalt, with a trace of lime.

As^2O^5	ZnO	CoO	NiO	H^2O		
37·17	30·52	6·91	2·00	23·40	=	100

according to Naumann, and isomorphous with cobalt-bloom. Massive or in crusts, with crystalline surface and fibrous structure. Cleavage perfect in one direction. Specific gravity = 3·1. Hardness = 2·5 – 3. Lustre of fracture-surface, silky. Colour, light carmine-red and peach-blossom red, of different shades. Streak, reddish-white. Translucent to subtransparent. (Köttig. J. pr. Chem. xlviii. 183; Naumann, *ibid.* 256.—Dana, ii. 418.)

KOKSCHAROWITE. A crystalline mineral occurring with ultramarine, and sometimes intergrown with it. It exhibits two very distinct directions of cleavage, inclined at an angle of 124°. Hardness = 5 to 5·5. It is sometimes colourless, with a strong lustre, sometimes brown and less lustrous. When heated, it becomes darker in colour, and easily melts to a white semitransparent glass (Nordenskiöld Jahresber. 1857, p. 681).—A specimen from the Slüdänka valley, near Lake Baikal, was found by R. Hermann (Jahresber. 1862, p. 726) to contain 45·99 per cent. silica, 18·20 alumina, 2·40 ferrous oxide, 12·78 lime, 16·45 magnesia, 1·06 potash, 1·53 soda, and 0·60 matter lost by ignition (=99·01). Specific gravity = 2·97.

KORITE. See Palagonite.

KOUMISS. A vinous liquid, which the Tartars make by fermenting mare's milk. A somewhat similar beverage is prepared in Orkney and Shetland.

KOUPHOLITE. Syn. with Prehnite.

KRABLITE. Syn. with Baulite (i. 520).

KRAMERIC ACID. An acid said by Peschier (J. Pharm. vi. 34; x. 348) to exist in rhatany root (*Krameria triandra*). It is crystalline, has a sour and astringent taste, and is not volatile. Its alkaline salts are crystallisable, and their solutions form a white precipitate with lead-salts, yellow with ferric salts. The barium-salt is said not to be decomposed by sulphuric acid or soluble sulphates.

Other chemists who have looked for this acid in rhatany root have not been able to find it.

KRANTZITE. A variety of retinite from the lignite of Latterf, near Bernburg. (See Retinite).

KRAURITE. Syn. with Dufrenite.

KREITTONITE. Syn. with Spinel.

KREMERSITE. Ruby-coloured octahedral chloride of potassium, from Vesuvius. Contains 55·15 per cent. chlorine, 16·89 iron, 12·07 potassium, 0·16 sodium, 15·56 ammonia and water. (Kremers, Pogg. Ann. lxxxiv. 79.)

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UVIGITE. Brochantite, from **Krisuvig in Iceland.**

KOÏTE. Syn. with CROCOÏSITE (ii. 109.)

RAPHITE. Syn. with TYROLITE.

METHINE. Syn. with CYAMETHINE (ii. 188).

NETHINE. Syn. with CYANETHINE (ii. 189).

NITE or *Cyanite.* A silicate of aluminium, $Al^2O^3.SiO^2$, occurring in triclinic
P. $\infty\breve{P}\infty$. $\infty\breve{P}\infty$. $\infty'P$. $\infty P'$. $2\breve{P}\infty$. Crystals usually bladed. Angles oP : $\infty\breve{P}\infty$
'; oP : $\infty\breve{P}\infty = 100° 50'$; oP : $\infty'P = 98° 58'$; oP : $\infty P' = 96° 42'$; $\infty\breve{P}\infty$:
$106° 16'$; $\infty'P : \infty P' = 97° 4'$; $\infty\breve{P}\infty : \infty'P = 145° 41'$; $\infty\breve{P}\infty : \infty P' =$
$\infty\breve{P}\infty : 2\breve{P}\infty = 159° 15'$. Cleavage perfect parallel to the smoother lateral
nperfect parallel to the base. Twins, of two kinds, with face of composition
nd planes $\infty\breve{P}\infty$, meeting at an angle; in one kind the planes oP are coin-
the other they form a re-entering angle. Also coarse-bladed, columnar;
ous. Hardness = 6 to 7·25. Specific gravity = 3·559; of white kyanite
f blue transparent kyanite from the Tyrol, 3·661 (Erdmann). Lustre
o pearly. Colour generally pale blue, often deeper along the middle of the
sometimes white or blue, with white margins; also grey, green, and black.
ncoloured. Translucent and sometimes transparent. The crystals may often
scratched on the lateral surface, while they are very hard at the ex-

e remains unaltered when simply heated before the blowpipe; melts to a
nt, colourless glass with borax, and gives a deep blue colour with cobalt-

yanite would contain 37·5 per cent. silica, and 62·5 alumina. The following
show that it does not deviate much from this composition:

	Arfvedson.		Smith and Brush.	Marignac.	Erdmann.	Smith and Brush.
	Rörass.	St. Gotthard.	New York.	St. Gotthard.	Rörass.	New York.
. .	36·4	36·9	37·03	36·60	34·40	37·20
na . .	63·8	64·7	61·90	62·66	61·86	59·02
oxide .	. .	. .		0·84	0·52	2·08
oxide .	. .	. .	. .	. .	0·19	
. .	. .	. .	0·85	. .	. .	1·03
	100·2	101·6	99 78	100·10	96·97	99·33

e occurs principally in gneiss and mica-slate. Transparent crystals are found
thard, in Switzerland; at Greiner and Pfitsch, in the Tyrol: also in Styria,
, and Bohemia; at Pontivy, in France; and at Villa Rica, in South America.
also in many localities in the United States: the specimens analysed by
d Brush were from Monro County, New York.
e (i. 499), from Bamle, in Norway, and xenolite (*q. v.*), have nearly the same
on as kyanite. Woerthite, from near St. Petersburg, containing 40·6 per
², 58·50 Al^2O^3, 1·00 MgO and 4·63 water, and Thomson's hydrobucholzite
from Sardinia), which contains 41·35 SiO^2, 49·53 Al^2O^3, 4·85 water and 3·12
re probably hydrous kyanites. Kyanite has also been observed altered to talc
te. (Dana, ii. 265.)

NOL. Syn. with PHENYLAMINE.

ATIN. Syn. with HORNBLENDE.

PHENINE or **CYAPHENINE.** $(C^{21}H^{15})'''N^3$.—A compound polymeric
ide of phenyl (benzonitrile), C^7H^5N, obtained by heating pulverised cyanate
um with chloride of benzoyl:

$$3C^7H^5OCl + 3CNKO = C^{21}H^{15}N^3 + 3KCl + 3CO^2.$$

hard neutral substance, exhibiting a crystalline fracture; melts at 224°, and
hout alteration at or a little above 350°; is soluble in water, slightly soluble
and ether. When heated with caustic potash, it decomposes, with copious
of ammonia. Sulphuric acid dissolves it, forming an acid whose barium-salt
in water. Strong hydrochloric acid does not dissolve it, even at the boiling
tric acid of ordinary strength is also without action upon it; but fuming
dissolves it, with great rise of temperature, but without evolution of gas;
raporating the solution or mixing it with water, nearly the whole of the
e is precipitated in the form of a nitro-compound, $C^{21}H^{12}(NO^2)^3N^3$, which
s in needles.

ATIN. Syn. with HORNBLENDE.

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KYNURENIC ACID. (Liebig, Ann. Ch. Pharm. lxxxvi. 125; cviii. 354.)—An acid sometimes deposited from the urine of dogs. From the urine of a dog whic had been fed on fat alone, or on fat mixed with a small portion of meat, Liebig obtaine it by evaporating, adding hydrochloric acid and leaving the liquid to stand for som time; the urine of dogs fed exclusively on lean meat yielded only traces. The deposi dissolves in lime-water, and on diluting the solution with water, and adding hydro chloric acid, kynurenic acid is deposited in very slender, colourless needles; from con centrated solutions, as a powder.

Kynurenic acid reddens litmus; when heated in a glass tube, it melts to a brow liquid, which then sublimes completely, forming a white silky crystalline sublimat and leaving a trace of charcoal. The precipitated acid is insoluble in alcohol and i ether; the sublimed acid dissolves in alcohol. It dissolves easily in boiling hydro chloric acid (whereby it is distinguished from uric acid), and in dilute sulphuric an nitric acids (in the latter without perceptible alteration, even on boiling). Cold con centrated sulphuric acid dissolves it without alteration; but on heating the solution, i turns brown, and, on addition of water, deposits a lemon-yellow, amorphous precipi tate, often mixed with crystals of the unaltered acid.

Kynurenic acid is a very weak acid. It dissolves easily in caustic alkalis, and, wit aid of heat, in alkaline carbonates, lime-water and baryta-water, neutralising the base and forming crystallisable salts. The *barium-salt* forms plumose groups of nacreou needles; the *calcium-salt*, stellate groups of short hard needles. Both salts are spar ingly soluble in water.

The acid is precipitated from the solution of the barium-salt by carbonic acid. I gave by analysis 61·6 to 61·9 per cent. carbon, 4·7 to 4·4 hydrogen, and 8·7 to 9· nitrogen. When heated alone or with lime, it yields a volatile oil, having the odou of benzonitrile.

KYPHOLITE. Syn. with SERPENTINE.

KYROSITE. White iron pyrites from the mine Briccius, near Annaberg.

L.

LABDANUM or **LADANUM.** A resin which exudes in drops from the leave and branches of the *Cistus creticus* and *C. cyprius*, shrubs growing in Greece an Turkey. It is generally black, solid, tenacious, and somewhat moist; softens betwee the fingers, and exhales an odour like that of ambergris. A sample analysed b Guibourt (*Histoire des Drogues*, iii. 601) contained 86 per cent. resin and volatile oi 7 wax, 1 aqueous extract, and 6 earthy matter and hairs. Commercial labdanum i often largely adulterated with black sand. According to Johnston, labdanum-resi contains 73·2 per cent. carbon and 10·0 hydrogen; a composition which may be approx mately represented by the formula $C^{20}H^{30}O^3$ (calc. 75·5 C, 9·4 H, and 15·1 O).

Labdanum in sticks is prepared in Portugal, Spain, and the South of France, b boiling the leaves and branches of *Cistus ladaniferus*.

LABRADORITE. *Labrador Felspar. Anhydrous Scolecite. Mauilite. Sil cite. Scolexerose.*—A mineral species belonging to the felspar group, and represente by the formula $M^2O.Al^2O^3.3SiO^2$, or $\left.\begin{matrix}(Si^2)^{xii}\\(Al^2)^{vi}\\M^2\end{matrix}\right\}O^{10}$, where M denotes calcium and sodium and occasionally also magnesium and potassium.

Labradorite occurs in triclinic crystals, in which oP : $\infty\breve{P}\infty$ = 86° 32′; oP : ∞' = 114° 48′; $\infty\breve{P}\infty$: $\infty P'$ = 119° 16′. It forms twins like those of albite (ii. 621 Cleavage perfect parallel to oP; distinct parallel to $\infty\breve{P}\infty$, in which direction also th faces are usually striated; indistinct parallel to $\infty P'$. Also massive, with distinc cleavage. Hardness = 6. Specific gravity = 2·67 to 2·76. Lustre of oP pearly passing into vitreous; elsewhere vitreous or subresinous. Colour usually grey, o various shades; also greenish, reddish, or yellowish. Some varieties, especially thos from Labrador, exhibit a beautiful play of colours when viewed in certain directions this effect is best seen in cut and polished specimens. Streak uncoloured. Fractur glistening. Translucent in a low degree. Less easily frangible than commo felspar.

Before the blowpipe on charcoal it fuses, with less difficulty than orthoclase, to colourless glass. With oxide of nickel and borax it forms a blue bead. When pul verised, it is entirely dissolved by hydrochloric acid, which does not attack eithe orthoclase or albite.

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es: *a.* From Campsie in Scotland, where it occurs in porphyritic greenstone t, Ed. N. Phil. J. 1852, p. 86). *b.* From Etna, where it occurs as a constituent v. Waltershausen, *Vulcanische Gesteine*, 1853, p. 24). *c.* From Faroë, ammer, J. pr. Chem. xxx. 385). *d.* From Labrador (v. Waltershausen e. From Eggersund, in Norway; violet-grey with brilliant play of colours n, Pogg. Ann. lxiii. 123). *f.* From the hypersthene-rock of Neurode, in luish-grey (v. Rath; Pogg. Ann. xcv. 538). *g.* From the gabbro of the same bluish-white (v. Rath, *ibid.*). *h.* From the melaphyre between Botzen and in the Tyrol; light greyish green. (Delesse, J. pr. Chem. xliii. 447; xlv. From the trachydolerite of Guadaloupe (Deville, *Rammelsberg's Mineral-* 598). *k. Scolexerose*, from Pargas, Finland (Nordenskiöld, Schw. J. xxxi. *Silicite*, from Antrim, Ireland. (Thomson, Phil. Mag. 1843, p. 417.)

O^2.	Al^2O^3.	Fe^2O^3.	CaO.	MgO.	Na^2O.	K^2O.	H^2O.	
67	27·89	0·31	10·60	0·18	5·05	0·49	. .	= 99·19
56	25·82	3·41	11·68	0·52	4·00	0·54	0·95	= 100·48
52	30·03	1·72	12·58	0·19	4·51	. .	. .	= 101·55
75	27·06	0·99	9·58	0·47	1·25	7·53	0·62	= 101·25
					4·70			
20	29·05	0·80	12·10	0·13			. .	= 98·98
55	28·32	2·44	11·61	0·48	4·52	0·64	0·62	= 101·18
31	27·31	1·71	10·57	0·78	4·81	1·55	2·20	= 99·24
					7·38			
23	27·73	1·50	8·28	0·93			0·95	= 100·00
25	29·89	. .	11·12	0·70	3·63	0·33	. .	= 99·92
13	29·23	. .	15·45	. .	. .	. .	1·07	= 99·88
		Fe^2O						
8	28·4	4·0	12·4	. .	. .	. .	0·6	= 100·2

umber of molecules of lime be supposed to be three times as great as that of he above formula, which then becomes $\left.\begin{matrix}\frac{3}{4}Ca''\\ \frac{1}{2}Na\end{matrix}\right\}O.Al^2O^3.3SiO^2$, gives 53·1 per 30·1 Al^2O^3, 12·3 CaO, and 4·5 Na^2O.

orite is more subject to alteration than other felspars; perhaps because it oth potash and soda. Partial decomposition is shown, either by the dimi- antity of these bases, or by the consequently increased proportion of silica. examples of unaltered labradorite in the preceding table are perhaps *e*, *f*, *g*, *k* and *l*, if the analyses are correct, afford decided indications of decomposi- numerous analyses of labradorite, and of felspars allied to it, see *Rammels- neralchemie*, pp. 597—603.

orite is a constituent of some lavas, as those of Etna and Vesuvius; of many s, as the oriental *verd antique* of Greece; of dolerite; of certain hornblende- nites, and syenites; of some porphyritic greenstones, as at Campsie in Scot- melaphyres, as in the Tyrol. On the coast of Labrador, whence it was brought, it is associated with hornblende, hypersthene, and magnetic iron na, ii. 238.)

RNIC ACID. An acid said to be contained, together with cytisine (ii. 311) neutral bitter principles, in the seeds, bark, and other parts of *Cytisus* . (T. Scott Gray, Arch. Pharm. [3] xlii. 160.)

s a substance well known in Europe under the different appellations of stick- lac, and seed-lac. The first is the lac in its natural state, encrusting small or twigs. Seed-lac is the stick-lac separated from the twigs, appearing in a l form, and probably deprived of part of its colouring matter by boiling. is the substance which has undergone a simple purification, as mentioned Beside these we sometimes meet with a fourth, called lump-lac, which is the nelted and formed into cakes.

he product of the *Coccus laccæ*, which deposits its eggs on the branches of a l Bihar, in Assam, and other parts of India. It appears designed to answer se of defending the eggs from injury, and affording food for the maggot in a anced state. It is formed into cells, finished with as much art and regularity ycomb, but differently arranged; and the inhabitants collect it twice a year, nths of February and August. For purification, it is broken into small pieces, nto a canvas bag of about four feet long, and not above six inches in circum- Two of these bags are in constant use, each of them being held by two men. is placed over a fire, and frequently turned, till the lac is liquid enough to ugh its pores; then taken off the fire, twisted in different directions, and at time dragged along the convex part of a plantain tree prepared for this pur- l while this is being done, the other bag is being heated, to be afterwards

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treated in the same way. The mucilaginous and smooth surface of the plantain tree prevents it from adhering; and the degree of pressure regulates the thickness of the coating of lac, at the same time that the fineness of the bag determines its clearness and transparency.

Stick-lac contains in 100 parts, resin 68, colouring extract 10, wax 6, gluten 5·5, extraneous substances 6·5; seed-lac contains resin 88·5, colouring extract 2·5, wax 4·5, gluten 2; shell-lac contains resin 90·9, colouring extract 0·5, wax 4, nitrogenous matter 2·8. (Hatchett.)

In India, lac is fashioned into rings, beads, and other trinkets; sealing-wax, varnishes, and lakes for painters, are made from it; it is much used as a red dye, and the resinous part, melted and mixed with about thrice its weight of finely-powdered sand, forms polishing stones. Lapidaries mix powder of corundum with it in a similar manner.

The colouring matter is soluble in water; but 1 pt. of borax to 5 of lac renders the whole soluble by digestion in water, nearly at a boiling heat. This solution is equal, for many purposes, to spirit varnish, and is an excellent vehicle for water-colours, as, when once dried, water has no effect upon it. Aqueous potash, soda, and carbonate of soda, likewise dissolve it; so does nitric acid, if digested with it in sufficient quantity for 48 hours.

The colouring matter of lac loses much of its beauty by keeping; but when freshly extracted, and precipitated as a lake, it is less liable to injury. Mr. Stephens, a surgeon in Bengal, sent home a large quantity precipitated in this way with alum; it afforded a good scarlet to cloth previously yellowed with quercitron.

Lac is the basis of the best sealing-wax. A good composition for red sealing-wax is 48 pts. of shellac, 12 oil of turpentine, 1 Peru balsam, and 36 vermillion. U.

LAC-DYE. A product obtained from lac, and used for producing a red dye, especially on wool. To obtain it, stick-lac freed from remains of stalks is pulverised and exhausted with warm water; and the colouring matter left on evaporating the solution is made into square cakes, and sent into the market as lac-dye. The residue yields seed-lac (*Lac in granis*), which is worked up into shell-lac. The proximate constitution of lac-dye is not exactly known; it contains, however, a considerable quantity of resin, and a red colouring matter, derived from the insects (*Coccus laccæ*), which may be partly extracted by water, more completely by acids, especially sulphuric or hydrochloric acid. The following processes are adopted for rendering the dye fit for use:

1. A mixture of 4 pts. lac with strong sulphuric acid is allowed to stand for 24 hours in summer and 48 in winter; then diluted and stirred with 3½ pts. of water, and again left to clarify. The clear liquid is poured into an iron pot, and mixed with the wash-water of the previous residue; the solution is mixed with a quantity of lime sufficient to neutralise $\frac{4}{5}$ of the sulphuric acid, and the precipitate of gypsum is removed: the liquid is then ready for use. This is the mode of preparation chiefly adopted in this country.

2. Thirty-two pts. of lac-dye are triturated with 10 to 12 pts. of sulphuric acid of specific gravity 1·85, or hydrochloric acid of specific gravity 1·13, each diluted with three times its weight of water. The mixture is left to itself for 48 hours in winter, or 24 in summer, and then mixed with the requisite quantity of river-water.

3. Thirty-two pts. of lac-dye are triturated with 12 pts. of hydrochloric acid of specific gravity 1·148, diluted with an equal weight of water; the mixture is left for 24 hours and frequently stirred, and then diluted with water.

To dye with the colour thus prepared, each pound is mixed with three-quarters of a pint of so-called lac-spirit, a solution of stannous chloride prepared by dissolving one pound of tin in 20 pounds of fuming hydrochloric acid, the mixture being left to itself for six hours before use. (Handw. d. Chem. iv. 748. See also *Ure's Dictionary of Arts, &c.* ii. 626.)

LACTAMETHANE. *Ethyl-lactamide*, $C^3H^{11}NO^2 = \begin{matrix} C^2H^5 \\ (C^3H^4O)'' \\ H^2 \end{matrix} \Big\} \begin{matrix} O \\ \\ N \end{matrix}$. (Wurtz, Ann. Ch. Phys. [3] lix. 175.)—This compound is formed when diethylic lactate is treated with aqueous ammonia, and the mixture is left to stand for one or two days; or when an alcoholic solution of the ether is saturated with ammonia and heated in a close vessel. The former process is, according to Wurtz, to be preferred. After expelling the excess of ammonia and water by evaporation in the water-bath, the lactamethane remains as a liquid, which solidifies on cooling to a beautiful crystalline mass, formed of broad, brilliant plates, slightly greasy to the touch. These crystals are soluble in water, alcohol, and ether; they melt at 62° or 63° to a colourless liquid, and boil at 219° under a barometric pressure of 761 mm., distilling without alteration.

The formation of lactamethane may be represented by the equation

$$\begin{matrix} C^2H^5 \\ (C^3H^4O)'' \\ C^2H^5 \end{matrix} \Big\} O + NH^3 = \begin{matrix} C^2H^5 \\ (C^3H^4O)'' \\ H^2 \end{matrix} \Big\} N + C^2H^6O.$$

Diethylic lactate. Lactamethane. Alcohol.

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By ebullition with potash, it is decomposed into ammonia and ethyl-lactate of potassium:

$$\underset{\text{Lactamethane.}}{\begin{matrix}C^2H^3\\(C^3H^4O)''\\H^2\end{matrix}\Big\}\begin{matrix}O\\N\end{matrix}} + KHO = \underset{\text{Ethyl-lactate of potassium.}}{\begin{matrix}C^2H^5\\(C^3H^4O)''\\K\end{matrix}\Big\}\begin{matrix}O\\O\end{matrix}} + NH^3.$$

G. C. F.

LACTAMIC ACID. Syn. with ALANINE (i. 63). It is also produced by the action of very strong solution of ammonia on chloropropionate of ethyl at 100°. (Kolbe, Ann. Ch. Pharm. cxiii. 220.)

Lactamate of ammonium (so called), $C^6H^{14}N^2O^4 = \begin{matrix}H^2\\(C^3H^4O)''\\(C^3H^4O)''\\H^4N\end{matrix}\Big\}\begin{matrix}N\\O.\\O\end{matrix}$—Formed by the action of ammonia-gas on lactic anhydride (DILACTIC ACID, p. 461) (Pelouze); or by saturating a solution of lactic anhydride in absolute alcohol with dry ammonia, and evaporating the solution. Tabular crystals, very easily soluble in water and alcohol. On adding dichloride of platinum to the solution, freed by boiling from excess of ammonia, only part of the nitrogen is precipitated as chloroplatinate of ammonium; but after boiling the filtrate for an hour, it gives a further precipitate with dichloride of platinum—a proof that part only of the nitrogen exists in the form of ammonium-salt. (Laurent, Compt. chim. 1845, p. 151.) G. C. F.

LACTAMIDE. $C^3H^7NO^2 = \begin{matrix}H\\(C^3H^4O)''\\H^2\end{matrix}\Big\}\begin{matrix}O\\N\end{matrix}$. (Isomeric with alanine or lactamic acid (i. 63), $C^3H^7NO^2 = \begin{matrix}H^2\\(C^3H^4O)''\\H\end{matrix}\Big\}\begin{matrix}N\\O\end{matrix}$.)—Obtained—1. By the action of ammonia gas on lactide (Pelouze; Wurtz and Friedel, Ann. Ch. Phys. [3] lxiii. 108).—2. By the action of an alcoholic solution of ammonia on lactide (Wurtz and Friedel, *loc. cit.*).—3. By saturating monethylic lactate with ammonia and leaving the liquid to stand. (Brüning, Ann. Ch. Pharm. civ. 197.)

It forms small prisms, which dissolve easily in *water* and *alcohol*, but do not combine either with acids or bases. It is decomposed, by boiling with alkalis or acids, into ammonia and lactic acid.

The above formula represents lactamide as derived from the double molecule $\begin{matrix}H^2O\\H^2N\end{matrix}\Big\}$ by the substitution of the radicle C^3H^4O for H^2. The substances described under the names lactamethane (p. 452), and lactethylamide (*vid. inf.*), are ethylised derivatives of lactamide; the former by the substitution of C^2H^3 for the hydrogen-atom of the water-residue contained in lactamide, the latter by the substitution of C^2H^5 for one of the hydrogen atoms of the ammonia-residue. These relations are expressed in the rational formulæ by which lactamethane, lactethylamide, and lactamide are respectively represented at the places referred to. G. C. F.

LACTETHYLAMIDE. $C^5H^{11}NO^2 = \begin{matrix}H\\(C^3H^4O)''\\C^2H^5.H\end{matrix}\Big\}\begin{matrix}O\\N\end{matrix}$. Isomeric with lactamethane (Wurtz and Friedel, Ann. Ch. Phys. [3] lxiii. 110). Formed by the action of ethylamine on lactide. When these two substances are brought together, the ethylamine immediately begins to boil. If the operation is performed in a close vessel, and with anhydrous materials, the whole solidifies to a crystalline mass. This product, when purified by one crystallisation from alcohol, melts at 48°, and may be cooled to 40° without freezing; but as soon as crystallisation has commenced, the thermometer rises to 46·5°. Lactethylamide distils without alteration at 260°. Its formation is represented by the equation

$$\underset{\text{Lactide.}}{C^6H^4O^2} + \underset{\text{Ethylamine.}}{C^2H^7N} = \underset{\text{Lactethylamide.}}{C^5H^{11}NO^2}.$$

Alkalis decompose it into ethylamine and alkaline lactate.

$$\underset{\text{Lactethylamide.}}{\begin{matrix}H\\(C^3H^4O)''\\C^2H^5.H\end{matrix}\Big\}\begin{matrix}O\\N\end{matrix}} + KHO = \underset{\text{Lactate of potassium.}}{\begin{matrix}H\\(C^3H^4O)''\\K\end{matrix}\Big\}\begin{matrix}O\\O\end{matrix}} + \underset{\text{Ethylamine.}}{C^2H^5.H^2N}.$$

G. C. F.

LACTIC ACID. *Milchsäure*, $C^3H^6O^3 = \begin{matrix}(C^3H^4O)''\\H^2\end{matrix}\Big\}O^2$. (Gm. xi. 472).—This acid was discovered by Scheele in sour milk, and first recognised as a peculiar acid by Berzelius. Braconnot found in the wash-liquor of the preparation of wheat-starch, in the fermented juice of mangold-wurzel, and other fermented vegetable extracts,

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an acid which he designated *nanceic acid*, but which was afterwards shown to be identical with the acid of sour milk. Berzelius demonstrated the presence of the same or an isomeric acid in the juice of the flesh of animals recently killed—a result which was confirmed by Liebig in his classical investigation of flesh-juice (see SARCOLACTIC ACID, p. 457). More recently, the chemical relations of lactic acid have been investigated by Strecker (Ann. Ch. Pharm. lxxxi. 247; xci. 352), Wurtz (Ann. Ch. Phys. [3] lix. 161), Wurtz and Friedel (*ibid.* lxiii. 101), and Kolbe (Chem. Soc. Qu. J. xii. 15); and the lactates have been chiefly studied by Pelouze (Ann. Ch. Phys. [3] xiii. 257), and by Engelhardt and Maddrell (Ann. Ch. Pharm. lxii. 83; lxx. 241).

Formation.—1. By a peculiar fermentation, the *lactic acid fermentation*, of various kinds of sugar, and of dextrin: this fermentation precedes the butyric acid fermentation. As all the substances of the sugar tribe have the same proportional composition as lactic acid, with a few atoms of water more or less, the transformation is easily explained: thus, with milk-sugar:

$$\underset{\text{Milk-sugar.}}{C^{12}H^{20}O^{10}} + 2H^2O = \underset{\text{Lactic acid.}}{4C^3H^6O^3}$$

The lactic fermentation requires a temperature between 20° and 40° C., and the presence of water and of certain ferments, viz., albuminoïdal substances in a peculiar state of decomposition, such as casein, gluten, or animal membranes, particularly the coating of the stomach of the calf (rennet), or dog, and bladder.

2. Tritylglycol, in presence of platinum-black, is converted into lactic acid by the oxygen of the air (Wurtz):

$$\underset{\text{Tritylglycol.}}{C^3H^8O^2} + O^2 = \underset{\text{Lactic acid.}}{C^3H^6O^3} + H^2O$$

3. Chloropropionic acid yields chloride of silver and lactic acid, when it is heated with water and oxide of silver. (Wurtz, Ann. Ch. Phys. [3] lix. 165):

$$\underset{\substack{\text{Chloropropionate of}\\ \text{silver.}}}{C^3H^4ClAgO^2} + H^2O = \underset{\text{Lactic acid.}}{C^3H^6O^3} + AgCl$$

Similarly, bromopropionic acid yields lactic acid and bromide of silver, when treated with oxide of silver in presence of water (Friedel and Machuca, Ann. Ch. Pharm. cxx. 286). Iodopropionic acid (formed by the action of iodide of phosphorus on glyceric acid) appears to yield a peculiar modification of lactic acid when treated as above. (Beilstein, *ibid.* p. 234.)

4. By the action of nitrous acid upon alanine; as when the vapours evolved from a mixture of starch and nitric acid, after being passed through a cold vessel which stops any undecomposed nitric acid, are conducted into aqueous alanine; the action is attended with copious evolution of nitrogen:

$$\underset{\text{Alanine.}}{C^3H^7NO^2} + \underset{\text{Nitrous acid.}}{NO^2H} = \underset{\text{Lactic acid.}}{C^3H^6O^3} + H^2O + N^2$$

5. Pyruvic (pyroracemic) acid, treated in aqueous solution with sodium-amalgam (Wislicenus, Ann. Ch. Pharm. cxxvi. 227), or with zinc in presence of dilute acetic acid (Debus, Chem. Soc. J. xvi. 260), is converted into a salt of lactic acid:

$$\underset{\text{Pyruvic acid.}}{C^3H^4O^3} + H^2 = \underset{\text{Lactic acid.}}{C^3H^6O^3}$$

6. When hydroxycyanide of ethylene, $\left.\begin{matrix}(C^2H^4)''\\ H\end{matrix}\right\}\begin{matrix}CN\\ O\end{matrix}$ (obtained from hydroxychloride of ethylene by double decomposition with cyanide of potassium), is boiled with aqueous alkalis, it is resolved into ammonia and (sarco-) lactic acid. (Wislicenus, Ann. Ch. Pharm. cxxviii. 6):

$$\underset{\substack{\text{Hydroxycyanide}\\ \text{of ethylene.}}}{C^3H^5NO} + 2H^2O = \underset{\text{Lactic acid.}}{C^3H^6O^3} + H^3N$$

Ethyloxycyanide of ethylidene, $\left.\begin{matrix}(C^2H^4)''\\ C^2H^5\end{matrix}\right\}\begin{matrix}CN\\ O\end{matrix}$ (obtained by digesting ethyloxychloride of ethylidene [ii. 600] with cyanide of potassium in a sealed tube), yields ordinary lactic acid, and a small quantity of ethyl-lactic acid, when similarly treated. (Wislicenus, *op. cit.* p. 14.)

7. Oxychloride of carbon combines directly with ethylene, forming chloride of lactyl:

$$COCl^2 + C^2H^4 = C^3H^4OCl^2,$$

whence lactic acid can be obtained by well-known processes. (Lippmann, Ann. Ch. Pharm. cxxix. 81; Ann. Ch. Phys. [4] i. 485.)

Preparation.—a. *From various kinds of Sugar.*—1. An aqueous solution of 100 pts. of grape-sugar (cane- or milk-sugar), exhibiting the density of 8° to 10° Bm., is mixed

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with 8 or 10 pts. of fresh sour cheese, as purchased in the market, or 100 pts. of sugar are dissolved in 100 to 150 pts. of milk, and such a quantity of water that the liquid exhibits a density of 10° Bm.; and either of these mixtures is placed, together with 50 pts. of chalk, in an open vessel, and exposed to the sun for several weeks, with frequent agitation, till the resulting lactate of calcium begins to change into butyrate (Pelouze and Gelis). As lactate of calcium is much less soluble than butyrate, the conversion of the former into the latter may be recognised, when strong solutions of sugar are used, by the diminution of the crystalline mass produced at first. If the process be too soon interrupted, a large quantity of sugar remains unaltered.

2. Six pounds of cane-sugar and half an ounce of tartaric acid (which serves to convert the cane-sugar into glucose) are dissolved in 26 pounds of boiling water; 3 pounds of levigated chalk added after two days, together with 4 ounces of stinking hand-cheese, suspended in 8 pounds of sour milk (decaying cheese favours the production of lactic acid and retards its conversion into butyric acid); the mixture set aside at a temperature between 30° and 35°, and well stirred every day till, in the course of six or eight days, it is converted into a stiff paste of lactate of calcium; this paste is boiled for an hour with half an ounce of quicklime and 20 pounds of water; the solution strained through a cloth filter and evaporated to a syrup; the crystalline mass which forms in four days, pressed, first by itself, then three or four times, after having been each time stirred up, with $\frac{1}{10}$ pt. of cold water; and the lactate of calcium thus purified is dissolved in twice its weight of boiling water. To the solution of every 32 pts. of the calcium-salt there is then added a mixture of 7 pts. oil of vitriol and 7 pts. water; the lactic acid, while still hot, is strained through linen to separate it from sulphate of lime; the filtrate obtained from 7 pts. of oil of vitriol is boiled with $1\frac{3}{4}$ pts. carbonate of zinc for a quarter of an hour (by longer boiling a very sparingly soluble basic salt is formed); the liquid is filtered boiling hot; the colourless crystalline grains of lactate of zinc which separate on cooling, are freed from sulphuric acid by washing with cold water; and additional quantities of crystalline grains are obtained by evaporating the mother-liquor, almost to the end. Lastly, 1 pt. of the zinc-salt is dissolved in $7\frac{1}{2}$ pts. of boiling water; sulphuretted hydrogen passed through the solution as long as sulphide of zinc is precipitated; and the filtrate boiled and evaporated on the water-bath to a syrup, whereupon 8 pts. of the zinc-salt yield 5 pts. of syrupy lactic acid (Bensch, Ann. Ch. Pharm. lxi. 174). By this process, 100 pts. of cane-sugar yield 117 pts. of lactate of calcium, which, if the sugar was white, is colourless, and does not require to be purified by pressure. If the carbonate of zinc contains lime and magnesia, these bases pass over to the lactic acid, which, after being evaporated to a syrup, must be dissolved in ether, and separated from the lactates of calcium and magnesium by filtration and evaporation. The calcium-salt may, however, without first preparing the zinc-salt from it, be freed by repeated crystallisation from a nitrogenous substance which obstinately adheres to it; its solution in the smallest possible quantity of water, mixed with a quantity of pure sulphuric acid not quite sufficient to decompose it; the mixture heated with alcohol till the sulphate of calcium is completely separated; the filtrate evaporated to a syrup; the syrup dissolved in ether; and the ethereal solution filtered and evaporated. (Engelhardt and Maddrell.)

Lautemann (Ann. Ch. Pharm. cxiii. 242) recommends the following modification of Bensch's process of preparation:—Retaining the proportions of sugar, tartaric acid, milk, and cheese indicated by the latter, he takes one-third more water, uses 1,200 grms. oxide of zinc (commercial zinc-white) instead of levigated chalk, and keeps the temperature as constantly as possible between 40° and 45° during the fermentation. After eight or ten days, the inside of the vessel is lined with white crystals of lactate of zinc, which can be obtained pure by one or two crystallisations from boiling water. The lactic acid prepared from the zinc-salt generally contains mannite, which does not completely crystallise out from the concentrated acid. To separate this, the aqueous acid is shaken up with ether, and then the ethereal layer is pipetted off and evaporated: it then leaves pure lactic acid.

3. The solution of 300 grms. of milk-sugar in 4 litres of milk is placed in the open air at a temperature of 25° to 30°, and neutralised with acid carbonate of sodium as often as it becomes sour, perhaps every two days; boiled when it no longer turns acid; filtered from the curd; carefully evaporated to a syrup; and the syrup dissolved in moderately warm alcohol of 38° Bm. By treating this filtered alcoholic solution of lactate of sodium with sulphuric acid to precipitate the sodium, and saturating the filtered lactic acid with chalk, crystallised lactate of calcium is obtained, and may be purified by further treatment. (Boutron and Frémy, J. Pharm. xxvii. 341.)

b. *From milk which has turned sour.*—1. Scheele evaporates sour whey to $\frac{1}{8}$; filters the liquid from the curd; precipitates the phosphoric acid from it with lime; filters; dilutes with 3 pts. water; precipitates the lime by careful addition of oxalic acid; filters; evaporates to the consistence of honey; extracts the lactic acid with alcohol;

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filters; dilutes with water, and evaporates. Berzelius digests the acid thus obtained with carbonate of lead; filters; precipitates the dissolved lead with sulphydric acid, filters, and evaporates.—2. The filtered solution of sour whey evaporated nearly to dryness, in strong alcohol, is mixed with alcoholic tartaric acid, as long as any precipitate of tartrate of potassium, sodium, and calcium is formed; the liquid decanted after 24 hours, and evaporated; the residue dissolved in water; the solution digested with carbonate of lead, till lead dissolves in it; the filtrate evaporated, neutralised with carbonate of barium, again filtered, and diluted with water; the whole of the barium precipitated with sulphate of zinc; and the filtrate evaporated till lactate of zinc crystallises out (Berzelius, Lehrb. Ausg. 5, v. 241. For the earlier methods of Berzelius, see Pogg. Ann. xix. 26). W. Engelhardt (Zeitschr. Chem. Pharm. 1861, p. 643) gives the following process for the preparation of lactate of zinc, from which he then obtains lactic acid by decomposing the hot solution of the zinc-salt with sulphydric acid, filtering and evaporating. Sour whey, to which $\frac{1}{20}$ of its weight of powdered milk-sugar has been added, is exposed to the proper temperature for the lactous fermentation, and every one or two days the free acid is neutralised with crushed carbonate of sodium taken from a previously weighed quantity. When at last the acid reaction does not reappear after two or three days, the liquid is heated to boiling, and sulphuric acid is added, drop by drop, so as to produce a distinct acid reaction. A quantity of sulphate of zinc equal in weight to the carbonate of sodium used is then dissolved in twice its own weight of water, and mixed with the other boiling liquid; the cheesy portions which immediately separate at the surface are removed by filtration through flannel-bag and the clear liquid is set aside to crystallise. After a day or two, the crystalline deposit of lactate of zinc may be removed and washed with cold water. The quantity remaining in the mother-liquor is insignificant. (For Cap and O. Henry's process, see J. Pharm. xxv. 138; also Ann. Ch. Pharm. xxx. 106.)

Properties.—Lactic acid is a colourless liquid of syrupy consistence, and specific gravity 1·215 at 20·5° C. It is inodorous, but has an intensely sour taste. It absorbs moisture from the air; dissolves in all proportions in water and alcohol, somewhat less freely in ether. It does not solidify at −24° C.

Decompositions.—1. *Dry distillation.* The acid, when very gradually heated, becomes less viscid; gives off at 130°, slowly and without evolution of gas, colourless water, together with a small quantity of lactic acid, and leaves a pale yellow, solid, easily fusible, extremely bitter residue of *lactic anhydride* (dilactic acid), $C^6H^{10}O^5 = 2C^3H^6O^3 - H^2O$. This residue remains unaltered up to 250°, but from 250° to 300°, at which temperature the decomposition is complete, gives off carbonic oxide gas, mixed at first with 4 or 5, and at last with 50 per cent. of its volume of carbonic anhydride (altogether a quantity of gas amounting to 33·1 per cent. of the lactic anhydride), and yields a distillate amounting to 90 per cent. of the anhydride, and consisting of *lactide*, $C^6H^8O^4 = 2C^3H^6O^3 - 2H^2O$ (p. 464), which crystallises out on cooling and likewise sublimes, of *lactone* (p 464), with small quantities of acetone, and an odoriferous oil insoluble in water, whilst a quantity of difficultly combustible charcoal remains, amounting to 6·9 per cent. of the anhydride (Pelouze). The anhydride, which remains undecomposed after heating to 240°, gives off, when kept for some time between 250° and 260°, carbonic oxide mixed with 3 or 4 per cent. of its bulk of carbonic anhydride (without any carburetted hydrogen); yields a yellowish distillate, which deposits crystals of lactide, and contains, in addition to the lactide (amounting to 14·9 per cent. of the anhydride), nothing but ordinary lactic acid, citraconic acid, aldehyde (amounting to 12·2 per cent. of the anhydride), but neither acetone nor lactone; and leaves 1 or 2 per cent. of shining, easily combustible charcoal. The aldehyde and the citraconic acid [?] are perhaps merely products of decomposition of the lactide, $C^6H^8O^4 = 2C^2H^4O + 2CO$. The ordinary lactic acid is formed from a portion of the anhydride by addition of the water set free by the conversion of the remainder into lactide. If the anhydride be distilled at 300° instead of 260°, less lactic acid and lactide are obtained, and more aldehyde (Engelhardt). Lactic acid, when heated, gives off pungent vapours which excite coughing, and yields a brown empyreumatic oil, together with an acid liquid, the acid of which is neither lactic nor acetic acid, but forms a viscid uncrystallisable salt with oxide of zinc (Braconnot, Ann. Ch. Phys. l. 375). It yields a watery distillate continually becoming more acid, the first portion of which, however, assumes a syrupy consistence when evaporated *in vacuo*, and if then gently heated in contact with the air, deposits crystals of lactide; it afterwards yields an oil and then a buttery mass, which solidifies in the neck of the retort, and when exhausted with cold ether, leaves scales and ultimately rhombic laminæ. Lastly, there remains a shining, tumefied charcoal. The acid which remains after partial distillation likewise contains a certain quantity of lactide; and on boiling this acid with ether and cooling the liquid, the lactide crystallises out (Corriol). By continued heating to between 180° and 200°, the acid is much more quickly converted into the anhydride, and yields a much more copious distillate of the unaltered acid, than between 130° and 140°;

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and if a platinum wire be immersed in the liquid, the lactic acid may be distilled over quite unaltered, and with regular ebullition (Engelhardt). If the lactic acid contains a small quantity of sulphuric acid, it yields only carbonic oxide gas, no carbonic anhydride (Pelouze). If it contains the smallest quantity of impurity, albumen for example, it does not yield any sublimate of lactide (Gay-Lussac and Pelouze). Lactic acid, heated slowly in contact with the air, boils gently, emitting a suffocating odour, swells up, blackens, and leaves a spongy charcoal. (Berzelius.)

2. Lactic acid (or ferrous lactate), mixed with a sixfold quantity of *oil of vitriol*, and gently heated, froths up briskly, acquires a dark-brown colour; gives off about $\frac{1}{4}$ of its weight of pure carbonic oxide gas; and at a higher temperature, yields about $\frac{1}{4}$ of its weight of a humus-like substance. (Pelouze.)

3. Boiling *nitric acid* converts lactic into oxalic acid. (Jules Gay-Lussac and Pelouze.)

4. Lactic acid and its salts, distilled with small quantities of *common salt, peroxide of manganese, sulphuric acid*, and water, yield chiefly aldehyde; with larger quantities, principally chloral. (Städeler, Ann. Ch. Pharm. lxix. 332.)

5. With aqueous *alkaline hypochlorites*, or *chlorous acid*, lactic acid is converted, first into oxalic acid, then, with effervescence, into carbonic anhydride. (Cap and Henry.)

6. When treated with *peroxide of barium* or of *lead*, it is converted chiefly into oxalic acid. (Cap and Henry.)

7. Distilled with *dilute sulphuric acid* and *peroxide of manganese* or *peroxide of lead*, it yields a large quantity of aldehyde, together with carbonic anhydride. (Liebig.)

8. Lactate of calcium distilled with *pentachlorides of phosphorus*, yields chloride of lactyl $(C^3H^4O)''.Cl^2$:

$$\left.\begin{matrix}C^3H^4O\\H^2\end{matrix}\right\}O^2 + PCl^5 = C^3H^4OCl^2 + PCl^3O + H^2O.$$

9. *Hydriodic acid*, or a mixture of di-iodide of phosphorus with a small quantity of water, reduces lactic acid to propionic acid:

$$\underset{\text{Lactic acid.}}{C^3H^6O^3} + 2H^2 = \underset{\text{Propionic acid.}}{C^3H^6O^2} + H^2O.$$

(Lautemann, Ann. Ch. Pharm. cxiii. 217.)

10. The action of *fuming sulphuric acid* upon lactic acid or lactate of calcium produces di-sulphometholic acid. (Strecker, Ann. Ch. Pharm. cxviii. 291.)

Sarcolactic or **Paralactic Acid.** In 1806, Berzelius discovered an acid in muscular flesh which he believed to be identical with the lactic acid prepared from milk. In 1847, Liebig (Ann. Ch. Pharm. lxii. 278 and 326) showed that this acid, though similar to the acid of sour milk in composition and in many other respects, nevertheless exhibited distinct differences from it in some of its salts. He therefore distinguished it by the name Sarcolactic acid (*Fleischmilchsäure*), in place of which Paralactic acid was proposed by Heintz (Pogg. Ann. lxxv. 391). In 1858, it was found by Strecker (Ann. Ch. Pharm. cv. 313) that, by heating paralactic acid for a long time to 130° or 140° and dissolving the resulting lactic anhydride in water, this acid may be transformed into ordinary lactic acid.

Preparation.—Chopped flesh is exhausted with cold water or dilute alcohol; the infusion is mixed with baryta-water; the albumin is coagulated by boiling, and removed by filtration; and the clear liquid is concentrated by evaporation Sulphuric acid is added to the syrupy residue, and it is shaken with ether, which then leaves paralactic acid when evaporated.

The difference between sarcolactic and ordinary lactic acids is most distinctly marked in their calcium- and zinc-salts (see below, Lactate of calcium and Lactate of zinc): the acids themselves are hardly to be distinguished.

Thebolactic acid. This is another modification of lactic acid found, by T. and H. Smith, of Edinburgh, in the mother-liquors of the preparation of morphine. Some of its salts are said to differ in certain respects from ordinary lactic acid (see Thebolactic acid).

Lactates. The best known salts of lactic acid are of the form $C^3H^5MO^3$: there are also acid salts containing $C^3H^5MO^3.C^3H^6O^3$, and double salts, $C^3H^5MO^3.C^3H^5M'O^3$. The existence of these acid and double salts led Gerhardt and other chemists to double the formula of lactic acid, making it $C^6H^{10}O^6$, and regarding the neutral salts as $C^6H^{10}M^2O^6$, and the acid salts as $C^6H^{11}MO^3$. But the relations between lactic and propionic acids have induced chemists in general to return to the lower formula of lactic acid, and to regard the acid lactates as constituted like the acid acetate of potassium (i. 17). Moreover, Wurtz's discovery of the diethylic lactate would render it necessary to regard the acid with the higher formula as tetrabasic, for which there is no warrant.

The crystalline lactates do not effloresce on exposure to the air, but give off water *in vacuo*, and the whole of it at 100°, excepting the acid nickel-salt which retains it till heated to 130°. They sustain a heat of 150° to 170° without decomposition; the

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zinc-salt may be heated even to 200°. They are for the most part sparingly soluble i cold water, and effloresce rapidly from their solutions: they are all insoluble in ethe

LACTATE OF AMMONIUM.—Obtained by neutralising the acid with ammonia. Form prismatic crystals which deliquesce and give off ammonia when exposed to the air.

LACTATE OF ANTIMONY.—Oxide of antimony dissolves in lactic acid or in aci lactate of potassium, but does not form a crystalline salt.

LACTATE OF BARIUM.—The *neutral* salt is uncrystallisable and very soluble i water. The *acid salt*, $Ba''(C^3H^5O^3)^2.2C^3H^6O^3$, is obtained by adding to a solution of th neutral salt a quantity of lactic acid equal to that which it already contains. It i then deposited in crystals which may be purified by washing with alcohol. It is n altered by exposure to the air or *in vacuo*. It dissolves easily in water. Gives off a aromatic odour at 100°.

LACTATE OF BISMUTH.—Only two basic salts are known: α. $2Bi'''(C^3H^5O^3)^3.Bi^2O$ This salt is obtained in needles by treating hydrate or carbonate of bismuth wit lactic acid, and evaporating. A better mode of preparing it is to mix the concentrate solutions of nitrate of bismuth and lactate of sodium—the latter in slight excess, whereb a crystalline pulp is precipitated consisting of lactate of bismuth mixed with nitr On redissolving this in a small quantity of water, and leaving the solution at rest, th lactate of bismuth is deposited in crystalline crusts.

β. $Bi'''(C^3H^5O^3)^3.2Bi^2O^3$.—By proceeding in the manner just described, but wit boiling solutions, or by adding nitrate of bismuth drop by drop to a solution of lactat of sodium, the salt β is precipitated as a powder unalterable in boiling water. I appears also to be produced by the solution of α.

LACTATE OF CADMIUM, $Cd''(C^3H^5O^3)^2$.—Obtained in small needles by dissolvin carbonate of cadmium in the acid. When deposited from a boiling solution, it i anhydrous. Insoluble in alcohol.

LACTATES OF CALCIUM.—The *neutral acetate*, $Ca''(C^3H^5O^3)^2.4H^2O$ and $Ca''(C^3H^5O^3)$ $5H^2O$, is obtained by saturating a boiling solution of lactic acid with carbonate c calcium, and evaporating the filtered liquid. It is also produced abundantly when solution of sugar mixed with cheese and carbonate of calcium is left to itself for som weeks at a temperature of 20° to 30° C. According to Corriol, the same salt is de posited from an infusion of *nux vomica* which has fermented for a few days. It is de posited from an aqueous or alcoholic solution in small, very white, mammellated crystal It dissolves in all proportions in water and in alcohol at the boiling heat, but col water dissolves only traces of it.

The characters of this salt differ somewhat according as it has been prepared wit lactic acid α extracted from muscular flesh (sarcolactic acid), or from lactic acid β produced by the fermentation of sugar.

The salt of the acid α, deposited from an aqueous solution, contains 2 at. water; tha of the acid β crystallised in the same way contains 5 at. $Ca''(C^3H^5O^3)^2.5H^2O$. Th lactate α retains its water of crystallisation at 100° longer than the salt β. Lastly, th salt α requires 12·4 pts. of water to dissolve it; whereas the salt β dissolves in 9·5 pt Pure lactate of calcium, dried at 100°, and containing $Ca''(C^3H^5O^3)^2$, loses water a 280°, and is converted into dicalcic dilactate, $C^6H^5Ca''O^5$ (DILACTIC ACID, p. 461) (Wurtz and Friedel.)

Acid lactate of calcium, $Ca''(C^3H^5O^3)^2.2C^3H^6O^3.3H^2O$, obtained by mixing a solutio of the neutral lactate with as much lactic acid as it already contains, forms crystallin masses resembling wavellite. It dissolves in absolute alcohol, gives off its water o crystallisation at 80°, and rapidly turns brown at a higher temperature.

Lactate of calcium and potassium.—Obtained by incompletely precipitating a solu tion of lactate of calcium with carbonate of potassium. It forms hard crystals solubl in water.

Lactate with chloride of calcium, $Ca''(C^3H^5O^3)^2.Ca''Cl^2.6H^2O$.—Obtained in prisms b mixing the solutions of the two salts, and concentrating the liquid considerably.

LACTATE OF CHROMIUM is an uncrystallisable salt.

LACTATE OF COBALT, $Co''(C^3H^5O^3)^2.6H^2O$.—Peach-blossom-coloured needles, nearl insoluble in cold water, moderately soluble in boiling water, insoluble in alcohol. It solution has a slight acid reaction.

LACTATE OF COPPER, $Ca''(C^3H^5O^3)^2.3H^2O$ and $2H^2O$, is obtained by precipitatin sulphate of copper with lactate of barium, or by boiling carbonate of copper with lacti acid. By the latter method a basic salt is also produced, from which the product mus be purified by recrystallisation or by addition of lactic acid.

Lactate of copper α (sarcolactate) crystallises in sky-blue nodules containing 3 at water, which it does not give up at 100° till after a considerable time; whereas β form larger crystals, of a green or very dark blue colour, and containing 2 at. water, whic they give off by simple desiccation over sulphuric acid. The salt α exposed to gradually increasing heat does not exhibit any change below 210°; but at that tem perature it takes fire and burns, leaving a residue of metallic copper. β heated in lik

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manner decomposes at 140°, leaving a residue of cuprous oxide. Lastly, α dissolves in 1·95 pt. cold water, and in 1·24 pt. boiling water, and in a small proportion of alcohol; whereas β requires for solution 6 pts. of cold water, 23 pts. boiling water, 115 pts. cold alcohol, and 26 pts. boiling alcohol.

Lactates of Iron.—*Ferrous lactate*, $Fe''(C^3H^5O^3)^2.3H^2O$, may be prepared by decomposing the calcium-salt with ferrous sulphate, or by mixing lactate of ammonium with ferrous chloride in presence of alcohol; also by boiling dilute lactic acid with iron-filings. It forms small crystals having a slight greenish tint; their solution oxidises but slowly on exposure to the air. This salt is sometimes used medicinally in the treatment of chlorosis.

Ferric lactate is a brown amorphous mass, deliquescent, and very soluble in water.

Lactate of Lead.—By treating carbonate of lead with boiling lactic acid, a neutral liquid is obtained, which when evaporated deposits a mass of small pellicles, and acquires an acid reaction.

Lactate of Magnesium, $Mg''(C^3H^5O^3)^2.4H^2O$ and $3H^2O$.—Obtained by dissolving magnesia in lactic acid. Crystallises in prisms permanent in the air, soluble in water, insoluble in alcohol. The salt α (sarcolactate) contains 4 at. water; the salt β contains 3 at. The salt α is also much more soluble in water and alcohol than β.

Lactate of Manganese, $Mn''(C^3H^5O^3)^2.3H^2O$.—Large, brilliant, amethyst-coloured crystals, moderately soluble in cold water, very soluble in hot water; soluble also in alcohol.

Lactates of Mercury.—*Mercurous lactate*, $(Hg^2)''(C^3H^5O^3)^2.2H^2O$. Rose-coloured or crimson crystals, obtained by mixing the boiling solutions of lactate of sodium and mercurous nitrate.

Mercuric lactate.—The neutral salt is not known. A basic salt, $Hg''(C^3H^5O^3)^2.Hg''O$, is obtained by boiling mercuric oxide with dilute lactic acid till the liquid is saturated. The solution yields by evaporation a yellow salt, insoluble in water, and a colourless salt which is very soluble. The latter, which has the composition above given, crystallises in shining prisms which effloresce rapidly in the air, and are very sparingly soluble in alcohol.

Lactate of Nickel, $Ni''(C^3H^5O^3)^2.3H^2O$.—Apple-green needles, very soluble in cold water, more soluble in hot water, insoluble in alcohol. The solution has a slight acid reaction. According to Engelhardt, the salt α gives off the whole of its water at 100°, but β does not part with the third atom before 130°.

Lactate of Potassium.—Very soluble, and crystallises with difficulty.

Lactate of Silver. $AgC^3H^5O^3.H^2O$.—Obtained by boiling carbonate of silver with lactic acid. It forms silky needles grouped in nodules, neutral to test-paper, blackening quickly by exposure to light, very soluble in warm alcohol, nearly insoluble in cold alcohol. The aqueous solution, when boiled for some time, acquires a fine blue colour, and deposits brown flakes. It may be heated to 80° without decomposing, but blackens and gives off gas at 100°. The air-dried salt contains 2 at. water, which it gives off *in vacuo*.

Lactates of Sodium.—*Monosodic lactate*, $NaC^3H^5O^3$. An amorphous, deliquescent mass, very soluble in water and absolute alcohol; ether precipitates it from its alcoholic solution. Dried at 140°, it possesses the above composition. (Wislicenus.)

Disodic lactate.—Monosodic lactate heated to 130° is acted on by sodium, hydrogen being liberated and a sodium-salt formed, which, together with unaltered monosodic lactate, contains disodic lactate. The product thus obtained is a bright yellow, very hard and brittle mass. It deliquesces quickly in the air. When covered with water, it is decomposed, with very perceptible development of heat, into monosodic lactate and hydrate of sodium. The deliquesced salt absorbs carbonic anhydride from the air; so that when it has been long exposed, absolute alcohol dissolves out monosodic lactate, leaving a residue of carbonate of sodium. Disodic lactate appears to dissolve without alteration in perfectly anhydrous alcohol. With iodide of methyl, it yields iodide of sodium and methyl-lactate of sodium. (Wislicenus, Ann. Ch. Pharm. cxiv. 49.)

Lactate of Strontium, $Sr''(C^3H^5O^3)^2.3H^2O$.—Neutral and very soluble.

Lactate of Tin. *Stannous lactate.* $Sn''(C^3H^5O^3)^2.Sn''O$.—This basic salt is obtained by mixing an acid solution of stannous chloride with lactate of sodium. It is a white crystalline powder, insoluble in cold water, very soluble in hydrochloric acid; soluble also in acetic acid after prolonged ebullition.

Stannic chloride mixed with lactate of sodium does not yield crystals, or a precipitate even after concentration to a syrup.

Lactate of Uranium.—Uranic lactate, $(U^2O^2)''(C^3H^5O^3)^2$, is obtained in yellow crystalline crusts by evaporating a solution of uranic oxide in lactic acid.

Lactate of Zinc, $Zn''(C^3H^5O^3)^2.3H^2O$ and $2H^2O$.—Prepared by boiling carbonate of zinc with lactic acid. The salt α (sarcolactate) is deposited, as the solution cools, in very dilute needles, irregularly grouped; on touching the vessel, these groups separate,

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and the whole of the liquid solidifies to a pulp. The salt β forms sometimes shining crusts, sometimes large needles irregularly grouped.

The salt α contains 1 at., the salt β $\frac{3}{2}$ at. water, which it gives off quickly at 100° whereas α requires heating for several hours to dehydrate it completely. β may be heated without alteration to 210°, whereas α begins to give off empyreumatic vapours between 100° and 150°.

The two salts also differ greatly in solubility. α dissolves in 2·88 pts. of boiling and 5·7 pts. of cold water; in 2·23 pts. of cold alcohol, and in about the same quantity with boiling heat. The salt β requires for solution 6 pts. of boiling water, 58 pts. of cold water, and is nearly insoluble in alcohol.

According to Liebig, the neutral salt prepared with lactic acid from sourcrout splits up, when its solution is mixed with alcohol, into a basic and an acid salt. Engelhard did not observe this decomposition of the zinc-salt prepared with lactic acid obtained by the fermentation of sugar.

Derivatives of Lactic acid.

Acetolactic acid. $C^5H^8O^4 = \begin{matrix} C^2H^3O \\ (C^3H^4O)'' \\ H \end{matrix}\Big\}O$. (Wislicenus, Ann. Ch. Pharm. cxxv. 60.)—Obtained from acetolactate of ethyl (*vid. inf.*) by heating it with water to 150° for two or three hours. It is a thick, syrupy liquid; very easily soluble in water and has an agreeable, purely acid taste, without any irritating after-taste. It is not volatile without decomposition, but is carried over to a considerable extent by water vapour; even then, however, it is partially decomposed into acetic and lactic acids. Under all circumstances, indeed, both the acid and its salts readily undergo decomposition into these two acids.

Acetolactate of barium, $Ba''(C^5H^7O^4)^2.4H^2O$.—Acetolactic acid dissolves carbonate of barium, with evolution of carbonic anhydride. The solution is warmed for a very short time with excess of the carbonate, in order to complete the neutralisation (longer heating would cause decomposition into lactate and carbonate); then filtered and evaporated to a syrup on the water-bath. This syrup becomes a tough mass on cooling, and dries up over sulphuric acid *in vacuo* to a brittle and pulverisable substance resembling gum. It then still retains 4 molecules of water, two of which are given off at 100°, the remainder only at 140°. Acetolactate of barium is very soluble in water, and dissolves also in absolute alcohol. Ether produces in the alcoholic solution a flocculent precipitate, which soon unites into a tough, sticky mass.

Acetolactate of copper.—Obtained as a blue-green, amorphous, gummy mass, by decomposing the barium-salt with sulphate of copper, and evaporating. It dissolves easily in water and alcohol, and becomes moist when exposed to the air.

Acetolactate of zinc, $Zn''(C^5H^7O^4)^2$.—A cold solution of acetolactate of barium is decomposed with an exactly equivalent quantity of sulphate of zinc, and the liquid is evaporated over sulphuric acid without the aid of heat. The gummy mass thus obtained contains imbedded crystals of lactate and acetate of zinc. To separate these, the acetolactate of zinc is dissolved out by a small quantity of absolute alcohol. By evaporating the solution *in vacuo*, the salt is left as a gummy mass, which, when thoroughly dried over sulphuric acid, is not decomposed at 110°. Its solutions, both aqueous and alcoholic, become quickly acid, owing to the extraordinary ease with which the salt decomposes into acetate and lactate of zinc, and acetic and lactic acids.

Acetolactate of ethyl, $C^7H^{12}O^4 = \begin{matrix} C^2H^3O \\ (C^3H^4O)'' \\ C^2H^5 \end{matrix}\Big\}O$.– Formed by the action of chloride of acetyl on monethylic lactate (p. 463). This reaction, which was first mentioned by Perkin (Zeitschr. Chem. Pharm. 1861, p. 166), has been further investigated by Wislicenus (*loc. cit.* p. 58).

Acetolactate of ethyl is a colourless, mobile liquid, of an agreeable, aromatic smell, recalling that of Calville-apples. It is neutral, and insoluble in water, but is gradually decomposed by it into alcohol and acetolactic acid (see above). It dissolves in alcohol and ether in all proportions, and is precipitated by water from its alcoholic solutions. Boiling point 177°, under 733 mm. pressure. Specific gravity, 1·0458 at 17°, water at the same temperature being taken as unity; vapour-density, found 5·70, calculated 5·54.

Benzolactic acid. $C^{10}H^{10}O^4$. (See vol. i. p. 561.)

Butyrolactic acid. $C^7H^{12}O^4 = \begin{matrix} C^4H^7O \\ (C^3H^4O)'' \\ H \end{matrix}\Big\}O$. (See vol. i. p. 697.—To the description there given of butyrolactate of ethyl, we add the following particulars.)

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Boiling point, 208°. Vapour-density, found 6·73, calculated 6·51. Heated with caustic potash in a sealed tube, it is decomposed into alcohol, and lactate and butyrate of potassium. (Wurtz, Ann. Ch. Phys. [3] lix. 177.—This mode of decomposition is important, since, were Kolbe's view of the constitution of butyrolactic acid correct, it ought to yield propionate and butylactate (oxybutyrate) of potassium when decomposed by potash. (Compare Ann. Ch. Pharm. cxiii. 234, 235, also vol. ii. p. 701 of this work.)

Dilactic acid. *Ankydrous lactic acid* (Pelouze), *Acide lactidique* (Laurent). $C^6H^{10}O^5 = \left.\begin{matrix}(C^3H^4O)''\\(C^3H^4O)''\\H^2\end{matrix}\right\}O^2$. This substance remains as a pale-yellow, amorphous, easily fusible mass, when lactic acid is exposed for some time to a temperature between 130° and 200°. It is converted into lactic acid, slowly by ebullition with water, quickly by the action of aqueous alkalis. By dry distillation, it is converted into lactide (p. 464). With gaseous ammonia it yields the compound $C^6H^{14}N^2O^4$, commonly called lactamate of ammonium, but more correctly dilactylamate of ammonium (p. 453).

Dilactate of calcium, $C^6H^8CaO^5$.—Obtained by heating lactate of calcium, previously dried at 100°, to 280°. It is much less soluble in absolute alcohol than lactate of calcium. (Wurtz and Friedel.)

Dilactate of ethyl. Monethylic dilactate, $C^8H^{14}O^5 = \left.\begin{matrix}(C^3H^4O)^2\\C^2H^5.H\end{matrix}\right\}O^3$, is formed by the action of chloropropionate of ethyl on lactate of potassium:

$$\underset{\text{Chloropropionate of ethyl.}}{\left.\begin{matrix}(C^3H^4O)''\\C^2H^5\end{matrix}\right\}Cl\,O} + \underset{\text{Lactate of potassium.}}{\left.\begin{matrix}(C^3H^4O)''\\HK\end{matrix}\right\}O^2} = \underset{\text{Monethylic dilactate.}}{\left.\begin{matrix}(C^3H^4O)^2\\C^2H^5.H\end{matrix}\right\}O^3} + KCl$$

It is a colourless, oily liquid, of specific gravity 1·134 at 0°; boiling point about 235°. It is decomposed, when heated with water in sealed tubes, into alcohol and lactic acid. (Wurtz and Friedel, Ann. Ch. Phys. [3] lxiii. 112.)

Monosulphodilactic acid, $C^6H^{10}O^4S$. (Schacht, Ann. Ch. Pharm. cxxix. 4.)—This acid was obtained as the product of an operation conducted with a view to the preparation of sulpholactic acid (p. 462). Instead of neutralising the aqueous solution of the crude product containing sulpholactate of potassium (see p. 462) with hydrochloric acid, it was neutralised with dilute sulphuric acid, and a further quantity of sulphuric acid was then added, sufficient to decompose the sulpholactate only. Monosulphodilactic acid then separated at the surface of the concentrated saline solution, and was obtained pure by solution in ether and evaporation under the air-pump.

Monosulphodilactic acid is soluble in water, alcohol, and ether, but does not crystallise. It contains the elements of two molecules of sulpholactic acid *minus* one molecule of sulphydric acid:

$$2C^3H^6O^4S - H^2S = C^6H^{10}O^4S.$$

By oxidation with dilute nitric acid, it yields dilactylsulphurous acid, $C^6H^{10}SO^7$ (*Dipropionschwefelsäure*, Schacht), the barium-salt of which is a white amorphous powder containing $C^6H^8Ba''SO^7$.

Ethyl-lactic acid. See Lactic Ethers (p. 463).

Lactylsulphurous acid. *Sulphopropionic acid*, $C^3H^6SO^4$.—This acid is formed by the action of fuming sulphuric acid on cyanide of ethyl, or on propionamide, in the process for preparing disulpholactic acid (Buckton and Hofmann, Chem. Soc. Qu. J. ix. 251); also when sulpholactic acid is oxidised with dilute nitric acid. (Schacht.)

Lactylsulphite of Ammonium is exceedingly soluble in water, and uncrystallisable. Absolute alcohol throws it down as a thick treacly mass.

Lactylsulphite of Barium, $C^3H^4Ba''SO^4$, crystallises from a saturated boiling solution in fine silky crystals, arranged in spherical groups. It may be dried at 170° without decomposition.

Dilactylsulphurous Acid. See above.

Lactyl- and dilactylsulphurous acids may be regarded as containing the radicles of lactic and sulphurous acids, and may be represented by the following rational formulæ:

$$\left.\begin{matrix}(C^3H^4O)''\\(SO)''\\H^2\end{matrix}\right\}O^2 \qquad \left.\begin{matrix}(C^3H^4O)''\\(C^3H^4O)''\\(SO)''\\H^2\end{matrix}\right\}O^4$$

Lactylsulphurous acid. Dilactylsulphurous acid.

Methyl-lactic acid. See Lactic Ethers (p. 464).

Succino-lactic acids. The only known representatives of these substances are

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diethylic succinolactate, $C^{11}H^{18}O^6$, and diethylic succinodilactate, $C^{14}H^{22}O^8$. *Diethylic succino lactate*, $\left.\begin{matrix}(C^2H^4O^2)''\\(C^3H^4O)''\\(C^2H^5)^2\end{matrix}\right\}O^2$, is an oily liquid, insoluble in water, boiling at 280° and of specific gravity 1·119 at 0°, formed by the action of chloropropionic ether on succinate of ethyl and potassium in presence of alcohol. It is decomposed, when heated with baryta-water, into alcohol and succinate and lactate of barium.

Diethylic succinodilactate, $\left.\begin{matrix}C^4H^4O^2\\(C^3H^4O)^2\\(C^2H^5)^2\end{matrix}\right\}O^4$, is a liquid boiling between 250° and 270°, produced by the action of chloropropionate of ethyl upon succinate of potassium (Wurtz and Friedel.)

Sulpholactic acid, $C^3H^6O^2S = \left.\begin{matrix}(C^3H^4O)''\\H^2\end{matrix}\right\}\begin{matrix}S\\O\end{matrix}$. (Schacht, Ann. Ch. Pharm cxxix. 1.)—The potassium-salt of this acid is formed when an intimate mixture of chloropropionate of potassium and sulphydrate of potassium is heated for four or five hours to a little above 100°:

$$\underset{\text{Chloropropionate of potassium.}}{C^3H^4KClO^2} + HKS = \underset{\text{Sulpholactate of potassium.}}{C^3H^5KO^2S} + KCl$$

To prepare the acid, the mixture of chloride, phosphate, and chloropropionate obtained by neutralising with carbonate of sodium the crude product of the distillation of lactate of calcium with pentachloride of phosphorus, is mixed with sulphydrate of potassium (1 molecule of the latter for each molecule of lactate used), and the solution is evaporated and the residue heated as above. The product of this operation is dissolved in water, saturated with hydrochloric acid, warmed to expel sulphydric acid, largely diluted, made slightly alkaline with ammonia, and precipitated with acetate of lead. The lead-precipitate is thoroughly washed with *cold* water, then decomposed with sulphydric acid, and the filtered liquid repeatedly evaporated to a syrup to remove the hydrochloric acid. The residue is dissolved in water and neutralised at the boiling heat with carbonate of barium, which causes a precipitate of phosphate of barium, while sulpholactate of barium remains in the solution. From this solution the acid is again thrown down as lead-salt; the precipitate is decomposed by sulphydric acid; and the resulting solution of the free acid is concentrated by evaporation on the water-bath.

Sulpholactic acid crystallises in broad needles, grouped together in bundles or brushes; it melts without decomposition below 100°, and solidifies in the crystalline form. It dissolves in water, alcohol, and ether, and may be boiled in dilute solution without decomposing. Nitric acid, not in excess, oxidises it to lactylsulphurous acid, $C^3H^6SO^5$ (*sulphopropionic acid*, Buckton and Hofmann). (*vid. sup.*)

Sulpholactate of barium, $C^6H^{10}Ba''O^4S^2$.—Crystallises in cauliflower-shaped masses; dissolves easily in water, insoluble in alcohol; it is not altered when dried at 100°.

Sulpholactate of lead.—Amorphous, and becomes brown on keeping.

Sulpholactate of potassium is obtained by double decomposition from sulpholactate of barium and sulphate of potassium. The solution evaporated *in vacuo* to a syrup deposits broad plates which are very deliquescent.

Sulpholactate of silver, $C^3H^5AgO^2S$.—A white, amorphous precipitate obtained by adding nitrate of silver to a solution of sulpholactate of barium. It is soluble in nitric acid, and decomposes below 100°.

Trilactic acid. The diethylic ether corresponding to this acid is known. (See Lactic Ethers.) H. W. and G. C. F.

LACTIC ANHYDRIDE. Dilactic acid (p. 461) was formerly called anhydrous lactic acid, or lactic anhydride. The true lactic anhydride is Lactide (p. 464).

LACTIC ETHERS. Owing to its peculiar constitution as a mono-basic diatomic acid, lactic acid is capable of forming three different ethers containing the same monatomic alcohol-radicle. Thus there are three lactates of ethyl, which may be represented by the following formulæ:

$\left.\begin{matrix}H\\(C^3H^4O)''\\H\end{matrix}\right\}O$ Lactic acid.

$\left.\begin{matrix}C^2H^5\\(C^3H^4O)''\\H\end{matrix}\right\}O$ Ethyl-lactic acid, $\left.\begin{matrix}H\\(C^3H^4O)''\\C^2H^5\end{matrix}\right\}O$ Monethylic lactate.

$\left.\begin{matrix}C^2H^5\\(C^3H^4O)''\\C^2H^5\end{matrix}\right\}O^2$ Diethylic lactate.

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that two—namely, ethyl-lactic acid and monethylic
presented by the empirical formula $C^5H^{10}O^3$. The
ese bodies will become apparent from the following
s one atom of hydrogen, which is readily replaceable
ve metal by the ordinary processes of saline double
replacement being an ordinary metallic lactate:
can be replaced by its equivalent of an alcohol
of etherification, the result being a neutral ether,
neral, can be decomposed into alcohol and alkaline
But lactic acid contains also another atom of
ses, can be removed, together with an atom of
Cl, H^2N, or other similar residues, and is therefore
ory of types as existing outside the radicle of the
by metals or alcohol radicles in the same manner
ferred to. The replacement of this second atom of
by other means than those usually employed for
ers; and when this is done, the resulting products
d by effecting a similar substitution in the case of
, monethylic lactate results from the substitution
hydrogen-atom of lactic acid, and ethyl-lactic acid
adicle for the second of the two hydrogen-atoms
cid. The degree of difference in the properties of
m the mode of combination of the alcohol- and
en by the special description of them which
ERS, ii. 914–916.)

IC LACTATE. *Lactic Ether.* $C^5H^{10}O^3 = (C^3H^4O)''\left\{\begin{matrix}H\\C^2H^5\end{matrix}\right\}O_2$

352.—Wurtz and Friedel, Ann. Ch. Phys. [3]
part of lactate of calcium and potassium (p. 458) is
of potassium; the thin, faintly-smelling distillate,
d 180°, is saturated with chloride of calcium, and
als are then obtained consisting of $CaCl.2(C^5H^{10}O^3)$;
erably pure lactic ether (Streecker).—2. Syrupy
olute alcohol, yields monethylic lactate very readily.

of specific gravity 1·0542 at 0°, and 1·042 at 13°.
6° under a barometric pressure of 753 mm. Vapour-
riedel); calculated, 4·07. Soluble in all proportions

soon becomes acid by contact with *water*, from the
. *Alkalis, alkaline earths*, and *oxide of zinc* decom-
ter.—2. *Potassium* dissolves in lactic ether with
s potassio-lactate of ethyl, $C^5H^9KO^3$ =

actate of potassium (*vid. infr.*). This substance

odide of ethyl, it yields iodide of potassium and di-
ether, mixed with alcoholic *ammonia*, and evapo-
p. 453).

ic acid, $C^5H^{10}O^3 = (C^3H^4O)''\left\{\begin{matrix}C^2H^5\\H\end{matrix}\right\}O_2$. (Wurtz, Ann.
w, Ann. Ch. Pharm. cxiv. 206; cxviii. 325; Bull.
potassium- and calcium-salts of this acid are ob-
ion of diethylic lactate with potash and milk of lime.
with iodide of methylene and acrylic acid) by the
form.
omewhat viscid liquid, of a purely sour taste. It
ergoing partial decomposition at the same time.
t in all proportions; but on addition of chloride of
ne aqueous solution, it separates as an oil. It be-
dify, in a mixture of salt and snow. Ethyl-lactic
h effervescence. It cannot be resolved into lactic
kalis; but when heated with concentrated hydriodic
of ethyl.
ost part very soluble, and difficult to obtain in the

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crystalline form. The *calcium-salt*, $C^{10}H^{18}Ca''O^6$, crystallises by slow evaporation of aqueous solution in colourless, prismatic crystals, united into stellate groups. Alcol dissolves it less readily than water, and deposits it in wart-shaped masses. The *silv salt*, $C^3H^9AgO^3$, crystallises from hot water in bunches of needles of a silky lustr treated with iodide of ethyl, it yields diethylic lactate. The *zinc-salt* dries up to gummy mass.

DIETHYLIC LACTATE, *Ethyl-lactate of ethyl*.—$C^7H^{14}O^3 = \left.\begin{matrix} C^2H^5 \\ (C^3H^4O)'' \\ C^2H^5 \end{matrix}\right\} O_2$. (Wurt Ann. Ch. Phys. [3] lix. 169.—Wurtz and Friedel, *ibid.* lxiii. 103.—Butlerow, An Ch. Pharm. cxviii. 328). This substance, which may be regarded as the ether of t acid last described, is produced:—1. By the action of ethylate of sodium on chloropr pionate of ethyl (*éther chlorolactique*, Wurtz).—2. By the action of iodide of ethyl ethyl-lactate of silver.—3. By the action of iodide of ethyl on potassio-lactate ethyl.

Diethylic lactate is a transparent, mobile liquid, of an agreeable ethereal odour. boils at 156·5° under a pressure of 757 mm. Its specific gravity at 0° is 0·920 vapour-density, found, 5·052 (calculated, 5·055).

It is insoluble in water, but soluble in alcohol and ether. By ebullition with alkali it is transformed into alcohol and an ethyl-lactate (*vid. supr.*); treatment with am monia converts it into lactamethane (p. 452); it unites directly with lactide, formi diethylic trilactate.

CHLOROLACTIC ETHER, *Éther chlorolactique*. Syn. with *Chloropropionate of eth* (see PROPIONIC ETHERS).

DILACTATE OF ETHYL. See Dilactic acid (p. 461).

DIETHYLIC TRILACTATE, $C^{13}H^{22}O^7 = \left.\begin{matrix} (C^3H^4O)^3 \\ (C^2H^5)^2 \end{matrix}\right\} O^4$. A thick, colourless liqui boiling about 270°, formed by heating diethylic lactate to 170° for several days wi lactide. Potash decomposes it into alcohol and lactic acid. A substance which a pears to be monethylic trilactate, $C^{11}H^{18}O^7 = \left.\begin{matrix} (C^3H^4O)^3 \\ C^2H^5.H \end{matrix}\right\} O^4$, is obtained as secondary product in the preparation of diethylic trilactate. (Wurtz and Friedel

Lactates of Methyl. METHYL-LACTIC ACID, $C^4H^8O^3 = \left.\begin{matrix} CH^3 \\ H \end{matrix}\right\} (C^3H^4O)'' O$, is the on compound belonging to this class that has hitherto been described. It is obtained heating disodic lactate (p. 459) to 110° or 120° with iodide of methyl. *Methyl-la tate of silver*, $C^4H^7AgO^3$, remains as a brittle, amorphous, gummy mass, when i aqueous solution is evaporated *in vacuo*. *Methyl-lactate of zinc* is very solub in water, and uncrystallisable; it dissolves also in absolute alcohol. (Wislicenu Ann. Ch. Pharm. cxxv. 53. G. C. F.

LACTIDE. (True) *Lactic anhydride*. $C^3H^4O^2 = C^3H^4O.O$. (J. Gay-Luss and Pelouze, Ann. Ch. Pharm. vii. 43; Pelouze, *ibid.* liii. 116; Engelhard *ibid.* lxx. 243; Wurtz and Friedel, Ann. Ch. Phys. [3] lxiii. 101.)—Produced the dry distillation of lactic acid. To prepare it, the product obtained by slowly di tilling lactic acid is evaporated at 100°, and the residue washed with cold alcohol, a crystallised from boiling alcohol. Lactide crystallises in rhomboidal plates of dazzli whiteness. It is inodorous; melts at 107°, and begins to boil at 250°, giving off whit irritating vapours, which sublime without alteration, and condense in crystals on co bodies. It is only slightly soluble in hot water, but is gradually converted into lact acid by ebullition with water, and quickly by the action of bases.

Ammonia converts it into lactamide (p. 453); ethylamine, into lactethylami (p. 453). It unites with diethylic lactate, forming diethylic trilactate (*vid. supr.*). G. C. F.

LACTIDIC ACID. Laurent's name for DILACTIC ACID (p. 461).

LACTIN and **LACTOSE.** Syn. with SUGAR OF MILK.

LACTONE, $C^3H^4O^2$.—A liquid possessing an aromatic smell, and boiling at abo 92°, produced, together with lactide, by the dry distillation of lactic acid. (Pelouz Ann. Ch. Phys. [3] xiii. 262.)

LACTUCA SATIVA. The common lettuce. This plant yields, according T. Richardson (Jahresber. 1847–48, No. 134, Table to p. 1074), 0·87 per cent. as containing:

K^2O	Na^2O	CaO	MgO	SO^3	SiO^2	P^2O^5	Ferric phosphate	NaCl	
46·01	5·29	6·05	2·17	3·89	20·23	8·52	trace	7·82	= 99·98

LACTUCARIUM. A brownish viscid substance obtained by evaporating t

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juice which exudes, by incision, from the leaves and stems of certain species of *Lactuca*, especially *Lactuca virosa*. It has a peculiar odour resembling that of opium, and acts as a narcotic. German lactucarium contains, according to Ludwig (Arch. Pharm. [2], 7, 129; Jahresber. 1847–8, p. 824), from 44·4 to 53·5 per cent. lactucone; a soft resin; about 4 per cent. of an easy fusible waxy body; lactucin, the chief active principle of the substance; lactucic acid; about 1 per cent. of oxalic acid; a non-volatile not bitter acid, which reduces oxide of silver; and a volatile acid smelling like valerianic acid, both in small quantity only; about 7 per cent. of albumin; at least 2 per cent. mannite; a small quantity of a neutral, not bitter, unfermentable substance, crystallising in rhombic pyramids; and from 3 to 6 per cent. ash, containing potash, soda, manganic oxide, ferric oxide, and a small quantity of lime.

LACTUCERIN. A substance, insoluble in water, contained in lactucarium, probably identical with lactucone.

LACTUCIC ACID. This substance is obtained by triturating lactucarium with an equal weight of dilute sulphuric acid, adding 5 pts. of alcohol of 84 per cent., filtering, shaking up the filtrate with slaked lime, decolorising with animal charcoal, evaporating, heating the residue to boiling with a large quantity of water, and evaporating the aqueous solution, after decolorising it with animal charcoal. A mixture of lactucic acid and lactucin then remains, and on dissolving this in boiling water, the lactucin crystallises out on cooling, and the remaining liquid yields, by evaporation, impure lactucic acid.

Lactucic acid thus obtained is a light yellow mass, amorphous at first, but becoming crystalline after a while; its colourless aqueous solution is coloured wine-red by alkalis, and when boiled with cupric sulphate and excess of soda, reduces the cupric to cuprous oxide. (Ludwig, Jahresber. 1847–48, p. 824.) According to Walz (N. Jahrb. Pharm. xv. 118), it is $C^{36}H^{36}O^{19}$.

LACTUCIN. A substance contained in lactucarium, and supposed to be its active principle. It is obtained by treating the extract with alcohol containing 2 per cent. of strong vinegar, diluting the solution with water, precipitating with basic acetate of lead, removing the excess of lead from the filtrate by sulphydric acid, evaporating at a gentle heat, digesting the residue in ether, and leaving the ethereal solution to evaporate. Ludwig and Kromayer (Arch. Pharm. [2] cxi. 1) prepare it by macerating lactucarium in 1½ pt. hot water for four days, then pressing the mass, again treating it with a little cold water, boiling it five times with fresh portions of alcohol (which leaves lactucone undissolved), and evaporating the extracts to half the bulk of the material used. The product is then precipitated with basic acetate of lead, and recrystallised from alcohol as above.

Lactucin is yellowish, fusible, bitter, soluble in 80 parts of cold water, moderately soluble in alcohol and in acetic acid, less soluble in ether, which deposits it by evaporation in the crystalline state. According to Kromayer (Arch. Pharm. [2] cv. 3), it crystallises in nacreous scales or rhombic tables, probably containing $C^{28}H^{26}O^{7}$ or $C^{28}H^{28}O^{8}$. According to Walz (N. Jahrb. Pharm. xv. 118), it is $C^{36}H^{36}O^{12}$. Nitric acid, of specific gravity 1·48, converts it into a resinous body quite devoid of taste. Strong sulphuric acid turns lactucin brown. Lactucin heated with potash gives off ammoniacal products (?). Its solutions are not precipitated by any reagent. (Buchner, Rep. Pharm. xliii. 1, Gm. xvi. 276.)

LACTUCONE. $C^{40}H^{60}O^{3}$ (?).—A crystalline substance extracted from lactucarium by boiling alcohol. It forms mammillated crystals, which, after purification by recrystallisation and treatment with animal charcoal, are colourless, insipid, melt between 150° and 160°, are insoluble in water, but dissolve very easily in alcohol, ether, and oils, both fixed and volatile. It yields acetic acid in large quantity by distillation. It may, however, be partly volatilised without decomposition in a stream of carbonic acid gas. It yields by analysis 80·56—81·25 per cent. carbon, and 10·91—11·33 hydrogen, numbers which agree nearly with the formula $C^{40}H^{64}O^{3}$. It is an indifferent substance, and is not affected by potash or by chlorine. Its alcoholic solution does not precipitate metallic salts dissolved in alcohol. (Lenoir, Ann. Ch. Pharm. lix. 83.)

LACTUCOPICRIN. An uncrystallisable substance, which remains in the mother-liquors of the preparation of lactucin by Ludwig and Kromayer's process (*vid. sup.*), after the greater part of that substance has been precipitated by basic acetate of lead. When freed from admixed lactucin and lactucone by ether, it forms a brown, amorphous, very bitter mass, having a faint acid reaction, soluble in water and alcohol. It contains 52·6 per cent. carbon, 6·8 hydrogen, and 36·6 oxygen, agreeing nearly with the formula $C^{28}H^{32}O^{10\cdot4}$, and is therefore produced from lactucin by assumption of water and oxygen. (Kromayer, *Die Bitterstoffe*, Erlangen, 1861, p. 79.)

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LACTYL, CHLORIDE OF. *Chloride of chloropropionyl.* $C^3H^4OCl^2 = C^3H^4ClO.C$ (Wurtz, Ann. Ch. Phys. [3] lix. 163.—Ulrich, Chem. Soc. Qu. J. xii. 23.)—Obtaine together with oxychloride of phosphorus, by gently heating a mixture of well-dri lactate of calcium with twice its weight of pentachloride of phosphorus. It is difficu to separate the whole of the oxychloride of phosphorus, but the chloride of lactyl m be obtained nearly pure by distilling the liquid, which passes over during the reactio in small quantities at a time, and collecting separately the portion which distils abo 140°. Chloride of lactyl is also formed by the direct combination of ethylene a oxychloride of carbon. (Lippmann.)

When freshly prepared, chloride of lactyl is a colourless liquid, but it soon becom dark coloured, giving off hydrochloric acid. Its boiling point seems to be above 140 but it is partially decomposed when distilled, the thermometer rising to 180° or 190°

It sinks to the bottom of *water* and gradually dissolves, forming hydrochloric a chloropropionic acids (PROPIONIC ACID, DERIVATIVES OF) (Ulrich). With absolu *alcohol*, it reacts very energetically, forming hydrochloric acid, chloride of ethyl, a chloropropionate of ethyl. (Wurtz's *ether chlorolactique.*) G. C. F.

LAGONITE. A ferric borate, $Fe^4O^3.B^2O^3.3H^2O$, occurring as an incrustation the Tuscan lagoons. (Bechi, Sill. Am. J. [2] xvii. 129.)

LAKE. This term is used to denote a species of pigment formed by precipitati colouring matters with some earth or metallic oxide. The principal red lakes are t *Carmine*, *Florence*, and *Madder lakes.*

For the preparation of carmine-lake, four ounces of finely pulverised cochine are poured into 4 or 6 quarts of rain or distilled water (which has been previous boiled in a pewter kettle), and boiled with it for six minutes longer (it is sometim recommended to add, during the boiling, two drachms of pulverised cream of tarta Eight scruples of Roman alum in powder are then added, and the whole is kept up the fire for one minute longer. As soon as the coarse powder has subsided, and t decoction has become clear, the latter is carefully decanted into large cylindrical vesse covered over and kept undisturbed, till a fine powder settles to the bottom. From t decanted liquor, which is still much coloured, the rest of the colouring matter may separated by means of tin-solution: it then yields a carmine-lake but little inferior the other.

For the preparation of Florentine lake, the sediment of cochineal remaining the kettle after the preparation just described may be boiled with the requisite quanti of water, the red liquor which remains after the preparation of the carmine likewi mixed with it, and the whole precipitated with the solution of tin. The red precip tate must be frequently washed with water. Exclusively of this, two ounces of fre cochineal, and one of crystals of tartar, are to be boiled with a sufficient quantity water, poured off clear, and precipitated with the solution of tin, and the precipita washed. At the same time, two pounds of alum are also to be dissolved in water, pr cipitated by caustic potash, and the white earth repeatedly washed with boiling wat Finally, both precipitates are to be mixed together in the liquid state, put upon a filt and dried. For the preparation of a cheaper sort, one pound of Brazil wood may employed in the preceding manner, instead of cochineal.

For the following process for making a *lake from madder*, the Society of Arts vot their gold medal to Sir H. C. Englefield. Enclose two ounces troy of the finest Dut crop madder in a bag of fine and strong calico, large enough to hold three or fo times as much. Put it into a large marble or porcelain mortar, and pour on it a pi of clear soft water, cold. Press the bag in every direction, and pound and rub it abo with a pestle, as much as can be done without tearing it, and when the water is load with colour, pour it off. Repeat this process till the water comes off but slight tinged, for which about five pints will be sufficient. Heat all the liquor in an earth or silver vessel, till it is near boiling, and then pour it into a large basin, into which troy ounce of alum dissolved in a pint of boiling soft water has been previously p Stir the mixture together, and while stirring, pour in gently about an ounce and h of a saturated solution of carbonate of potassium. Let it stand till cold to settle; po off the clear yellow liquor; add to the precipitate a quart of boiling soft water, stirri it well; and when cold, separate by filtration the lake, which should weigh half ounce. If less alum be employed, the colour will be somewhat deeper; with less th three-fourths of an ounce, the whole of the colouring matter will not unite with t alumina. Fresh madder root is equal, if not superior, to the dry.

Almost all vegetable colouring matters may be precipitated into lakes, more or le beautiful, by means of alum or oxide of tin. U.

Yellow lakes are prepared chiefly with decoctions of the berries of vario species of *Rhamnus*, also of fustic, weld, quercitron, &c.; the decoctions, mixed wi carbonate of potassium in greater or smaller quantity as the colour is to be lighter darker, being poured into a hot solution of alum quite free from iron. The colo

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he still moist precipitate with tin-solution.—As many
ain a large quantity of tannin, it is usual, in order to
them, to mix them, in the first instance, with a con-
which precipitates the tannin.
ained in like manner by precipitating turmeric or
alum. A common kind of yellow-lake is obtained by
above, with clay, marl, or chalk; better, however, by
berries with 25 to 30 pts. water containing 1 pt. of
on 3 or 4 pts. of pounded chalk, and leaving it for
then decanting the liquid, and washing and drying
nt is desired, a small quantity of burnt or slaked lime

repared, since Prussian-blue, ultramarine, cobalt-blue,
every purpose for which they could be required. If
saturating the solution of sulphindigotic acid with
ad of potash, it is obtained of a still finer colour.
ulphindigotic acid is mixed with alum-solution, and
carbonate of potassium, whereby a peculiar blue lake
od mixed with alum yields a violet, and, on addition
e, if the solutions are precipitated in the cold with

pared by mixing blue and yellow lakes. A very good
exhausting 1 lb. of bruised coffee-berries with 10 lbs.
liquid from 2½ to 3 lbs. of sulphate of copper. The
austic potash, the coffee-extract being kept in excess
e cupric oxide. The precipitate, which weighs about
d, is moistened with a small quantity of vinegar, and
air, whereby its colour is heightened.

ED.

WAD.

ivided carbon, obtained by collecting the smoke of an
or resin. (See CARBON, i. 760.)

An old name for the snowy flakes of white oxide
en zinc is burned.

o-carbonate of lead, $PbSO^4.PbCO^3$, or $\left.\begin{matrix}(SO^2)''\\(CO)''\\Pb^2\end{matrix}\right\}O^4$,

ic crystals, cleavable in two directions, sometimes
t Leadhills, Scotland, in Siberia, at Tanné in the
Hardness = 2 to 2·0. Specific gravity = 6·3 to 7.
of others, adamantine, inclining to resinous. Streak
pale-yellow, or grey. Transparent or translucent.
nalysis (Ed. Phil. J. iii. 17), 53·5 per cent. sulphate,
ch is very near the calculated composition. Before
, which becomes white on cooling. Dissolves in nitric
ence.

eral consisting of a mixture of brucite and hydromag-
er County, Pennsylvania (Dana, ii. 457).

Lantalic acid, Laurent.) A product, according to
ii. 216), of the oxidation of uric acid, by a mixture of
tash. The result of the process, which is somewhat
e of potassium, which is dissolved in water, mixed
from the precipitated oxalate of lead; the lantanurate
he filtrate by ammonia, washed, suspended in water,
hydrogen. The filtrate, on evaporation, yields lanta-
ly soluble in water, insoluble in alcohol: its solution
be a dibasic acid. It forms a normal- and an acid
ch is syrupy, the latter crystallisable. The solution
vith ammoniacal acetate of lead, a white precipitate,
ol, soluble in acetic acid or basic acetate of lead.—
er, the acid potassium-salt gives a white precipitate,

f the lead-salt to be $C^5H^2Pb''N^2O^3$, whence that of the
oses to double the formula. According to Gerhardt
probably identical with allanturic acid. F. T. C.

carbonate of lanthanum (and didymium) (La; Di)″
ate of cerium. (See CARBONATES, i. 785.)

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LANTHANUM. *Atomic weight*, 92·8; *Symbol*, La. This metal appears to constantly associated with cerium and didymium. Mosander showed in 18 (Pogg. Ann. xlvi. 648; xlvii. 207) that the red-brown oxide obtained from cerite the manner described under Cerium (i. 831), and originally regarded as the oxi of a single metal, contained the oxide of another metal which he called lanthanu (from λανθάνειν, because it had previously been concealed in the oxide of cerium); a subsequently, in 1841 (Pogg. Ann. lvi. 504), he discovered that this supposed oxi of a single metal, lanthanum, was really a mixture of the oxides of two disti metals, for one of which the name lanthanum was retained, while the other was call didymium (δίδυμοι, twins).

The separation of lanthanum and didymium from cerium may be effected by either the methods described under cerium (i. 831, 832). The second and third are easier a more expeditious than the first. If the solution obtained by treating the crude re brown oxide with dilute nitric acid be evaporated to dryness, and the residue treat with nitric acid diluted with at least 200 pts. of water, a solution will be obtained qui free from cerium (Marignac). Boiling the red-brown oxide with chloride of amm nium also yields a solution of lanthanum and didymium free from cerium. In bo cases, however, it is best to test a portion of the solution for cerium by precipitati with excess of caustic potash, and passing chlorine through the solution. The presen of cerium, even in a very small quantity, will be indicated by the formation of a yell precipitate, after the liquid, supersaturated with chlorine, has been left in a close ves for several hours.

Holzmann, (J. pr. Chem. lxxv. 321; Rép. Chim. pure, i. 241), prepares pure la thanum-salts from the liquid which remains after the precipitation of basic ce sulphate in Bunsen's process for the separation of cerium (i. 832). This liquid, whi contains both lanthanum and didymium, is evaporated (during which process a lar additi nal quantity of cerium separates as basic sulphate) and heated till the great part of the free acid is expelled. The sulphates of lanthanum and didymium, whi then separate out, are dissolved in water containing a little nitric acid, and the solutic together with the mother-liquor, is precipitated with oxalic acid; the precipita mixed with an equal weight of *magnesia alba*, is heated for some time to low re ness; the resulting dark brown oxide is digested with small quantities of dilute nitr acid, which dissolves scarcely anything but the oxides of lanthanum, didymium a magnesium; and the filtrate is boiled for some time with magnesia to separate the la traces of cerium. The liquid is then again precipitated with oxalic acid; the dried a ignited precipitate dissolved in dilute nitric acid; the solution precipitated by sulpha of potassium; the precipitated lanthano- and didymio-potassic sulphates digested wi dilute carbonate of sodium, and the resulting carbonates dissolved in dilute sulphuric aci

A solution free from cerium having been obtained, the separation of the lanthanu and didymium is effected by the different solubilities of their sulphates. To conve them into sulphates, if not already in that form, the solution is treated with excess a caustic alkali, and the washed precipitate dissolved in dilute sulphuric acid. T mode of proceeding varies according as the lanthanum or the didymium is in excess.

1. When the lanthanum is in excess, in which case the solution has but a fai amethyst tinge, the liquid is evaporated to dryness, and the residue heated in a platinu dish to a temperature just below redness, to drive off the excess of acid, and render t sulphates perfectly anhydrous. The residue is then dissolved in rather less than s times its weight of water, at about 2° or 3° C. (36° F.), the salt being reduced powder and added in successive small portions, and the vessel containing the liqu being immersed in ice-cold water. Without these precautions, the temperature of t liquid may be raised several degrees, in consequence of the heat evolved by the comb nation of the anhydrous sulphates with water; and, in that case, crystallisation w commence, and rapidly extend through the whole mass of liquid, as these sulphates a much less soluble in warm than in cold water; but if the liquid be properly cooled, t whole dissolves completely. The solution is next to be heated in the water-bath about 40° C. (104° F.); the sulphate of lanthanum then crystallises out, accompani by only a small quantity of sulphate of didymium. To purify it completely, it is aga rendered anhydrous, re-dissolved in ice-cold water., &c., and the entire process repeat ten or twelve times. The test of purity is perfect whiteness, the smallest quantity didymium imparting an amethyst tinge (Mosander). This process succeeds be when a considerable quantity of the mixed sulphates is operated on.

2. When the didymium-salt is in excess, in which case the liquid has a decided ros colour, separation may be effected by leaving the solution containing excess of acid, a warm place for a day or two. The sulphate of didymium then separates in lar rhombohedral crystals modified with numerous secondary faces; and, at the same tim slender, needle-shaped, violet-coloured crystals are formed, containing the two sulphat mixed. The rhombohedral crystals, which are nearly free from lanthanum, a

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removed, and the needles, together with the mother-liquid, treated as in the first method, to obtain sulphate of lanthanum. (Mosander.)

In both cases, the separation may be greatly facilitated by first dissolving the mixed oxides of the two metals in a large excess of nitric acid, and precipitating in successive portions by oxalic acid; the first precipitates thus formed have a much deeper rose-colour, and are much richer in didymium than the latter. The separation thus effected is very imperfect in itself, but it greatly facilitates the subsequent separation of the sulphates, which is much more rapid when one of the sulphates is in great excess with regard to the other. (Marignac.)

Metallic lanthanum is obtained by decomposing the anhydrous chloride with sodium, and dissolving out the chloride of sodium with alcohol of specific gravity 0·833. It is a dark, lead-grey powder, soft to the touch, and adhering when pressed.

Lanthanum appears to form only one series of compounds, in which it is diatomic. *e.g.* the *chloride* $LaCl^2$; the *protoxide* LaO.

LANTHANUM, CHLORIDE OF, $LaCl^2$, is obtained in the anhydrous state by igniting the oxide in a current of hydrochloric acid gas (Mosander), or by dissolving the oxide in hydrochloric acid, evaporating the solution, mixed with sal-ammoniac, to dryness, and heating the residue till the sal-ammoniac is expelled. It then remains as a radio-crystalline mass, which deliquesces in moist air, and dissolves easily in alcohol. (R. Hermann, J. pr. Chem. lxxxii. 385.)

A *hydrated chloride*, $LaCl^2.4H^2O$, is obtained as a radio-crystalline mass, by evaporating a solution of the oxide to a syrup, and leaving it over oil of vitriol. When heated in moist air, it gives off water and hydrochloric acid, leaving a mixture of chloride of lanthanum and an oxychloride containing $3LaO.LaCl^2$.

Chloromercurate of Lanthanum, $LaCl^2.3HgCl^2.8H^2O$, is obtained by evaporating a solution of the component chlorides, in colourless cubes, easily soluble in water, but not deliquescent. (Marignac, Ann. Min. [5] xv. 272.)

LANTHANUM, DETECTION and ESTIMATION OF. 1. *Reactions.* Pure lanthanum-compounds fused with borax before the blowpipe, form a perfectly colourless bead; the slightest tinge of amethyst is an indication of the presence of didymium.

Lanthanum-salts in solution are colourless, and have an astringent taste. With caustic *potash* or *soda*, they yield a white bulky gelatinous precipitate of the hydrated oxide, which is insoluble in excess of the alkali, but dissolves completely in chlorine-water, without forming any yellow deposit. *Ammonia* throws down a basic salt. *Oxalic acid* or *oxalate of ammonium* forms a white flocculent precipitate, which does not become crystalline. In other respects the solutions resemble those of cerous salts (i. 833), especially in forming with sulphate of potassium a white crystalline precipitate quite insoluble in excess of the reagent.

2. *Estimation and Separation.*—Lanthanum is best precipitated from its solutions by oxalate of ammonium. The precipitated oxalate, ignited in a covered platinum crucible, is converted into the anhydrous oxide, La^2O, containing 85·4 per cent. of the metal.

The methods of separating lanthanum from most other metals are the same as those adopted for cerium and didymium. The separation of lanthanum from cerium itself may be effected by precipitation with an alkaline hypochlorite, or by boiling the mixed oxides in a solution of sal-ammoniac (i. 832). No method of separating lanthanum from didymium, sufficiently exact for quantitative analysis, has yet been discovered.

3. *Atomic Weight of Lanthanum.*—Mosander, by the analysis of sulphate of lanthanum, estimated the atomic weight of the metal (diatomic) at 92·8. Marignac (Ann. Ch. Phys. [3] xxvii. 209), by a similar method, obtained a somewhat higher number, viz. 94·08. Holzmann (J. pr. Chem. lxxv. 321), from the mean of his analyses of the sulphate and of the iodate, obtained the number 92·8; and R. Hermann (*ibid.* lxxxii. 385), from his analyses of the carbonate, sulphate, and chloride, obtained 92·88. Mosander's determination may, therefore, be regarded as fully confirmed.

LANTHANUM, FLUORIDE OF. Sulphate of lanthanum forms, with fluoride of sodium, a white flocculent precipitate, sparingly soluble in hydrochloric acid. (Hermann.)

LANTHANUM, OXIDES OF. Lanthanum forms two oxides, viz. a *protoxide*, LaO, and a *peroxide*, the composition of which has not perhaps been exactly ascertained.

The protoxide is obtained by igniting the hydrate, carbonate, or oxalate, first in contact with the air, afterwards in contact with the reducing gases of the flame. It then forms white lumps having the same texture as the peroxide, and a specific gravity of 5·94. When exposed to the air, it takes up water and carbonic acid, and in contact

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with water is converted into the hydrate, LaH^2O^2, which is a soft white powder resembling slaked lime. By precipitating a salt of lanthanum with potash or soda, the hydrate is obtained as a bulky, translucent precipitate, which rapidly absorbs carbonic acid. Both the hydrate and the anhydrous protoxide dissolve easily in acids, without evolution of gas.

The peroxide, said to have the composition $La^{64}O^{63}$ or 64LaO.O, is obtained by igniting the carbonate, oxalate, or nitrate, in contact with the air. It is a light brown or brownish-grey substance, which dissolves in sulphuric, nitric, or acetic acid, with evolution of oxygen, and in hydrochloric acid with evolution of chlorine.

LANTHANUM, OXYCHLORIDE OF, $La^4Cl^2O^3 = LaCl^2.3LaO$, remains on heating the hydrated chloride (p. 469), and after washing with water, forms a white powder, insoluble in water, but dissolving slowly in hydrochloric or nitric abid.

LANTHANUM, OXYGEN-SALTS OF. The solutions obtained by dissolving either of the oxides of lanthanum in acids, are colourless and have an astringent taste. Most salts of lanthanum are soluble in water; but the carbonate, borate, and phosphate are insoluble. Lanthanum has a great tendency to form basic salts, by precipitation with ammonia for example. Many of these salts, the basic nitrate and chloride (oxychloride) for instance, run through the filter as milky liquids during washing. If the precipitate be boiled, the whole runs immediately through the filter; but if it be left in the moist state for a few days, it is converted into a neutral salt, which dissolves in water, while carbonate of lanthanum remains on the filter. Sulphate of lanthanum resembles the corresponding salts of cerium and didymium, in forming with sulphate of potassium a crystalline double salt, sparingly soluble in pure water, and quite insoluble in water saturated with sulphate of potassium.

LANTHANUM, SULPHIDE OF, LaS, is obtained by igniting the metal in vapour of sulphide of carbon, as a yellow powder, which is decomposed by water, with evolution of sulphydric acid, and formation of the white hydrate of lanthanum. The sulphide may also be obtained by igniting the oxide in vapour of sulphide of carbon, or by fusing it with sulphide of sodium; but it is then of a fiery yellow colour, and when examined by the microscope, is seen to be made up of fine crystals. (Mosander.)

LAPATHIN. The name given by Buchner and Herberger (Rep. Pharm. xxxviii. 337), to a substance which they obtained in a very impure state from the root of *Rumex obtusifolius* (the officinal *Radix lapathi acuti*): it has since been shown to be identical with chrysophanic acid (i. 958).

LAPIS LAZULI. *Ultramarine. Lasurstein.*—A silicate of sodium, calcium, and aluminium mixed with a sulphur-compound of sodium. It occurs sometimes in rhombic dodecahedrons, with imperfect dodecahedral cleavage, but more commonly massive and compact. Hardness = 5·5. Specific gravity = 2·38 to 2·45. Lustre vitreous. Colour rich Berlin or azure blue. Translucent to opaque. Fracture uneven. Before the blowpipe it fuses to a white glass, and if calcined and reduced to powder, loses its colour, and gelatinises in hydrochloric acid. With borax, it effervesces and forms a colourless glass.

Analyses:—1. From the East: *a.* Klaproth (*Beitrage*, i. 189); *b.* L. Gmelin (Schw. J. xiv. 329); *c.* Varrentrapp (Pogg. Ann. xlix. 515); *d.* Köhler (*Rammelsberg's Mineralchemie*, p. 710); *e.* Schultz (*ibid.*).—2. From Vesuvius: L. Gmelin (*loc. cit.*).—3. From the Andes: *a.* Field (Chem. Soc. Qu. J. iv. 331); *b.* Schultz (*loc. cit.*):—

	1					2	3	
	a	*b*	*c*	*d*	*e*		*a*	*b*
Silica	62·0	49	45·50	45·33	43·26	47·1	66·9	45·70
Chlorine	. .	. .	. .	0·42	. .	. .	. .	. .
Sulphuric anhydride	5·4	2	5·89	3·22	5·67	1·2	. .	4·32
Alumina	20·0	11	31·76	12·33	20·22	18·5	20·0	25·34
Ferric oxide	4·0	4	1·23	2·12	4·20	13·7	0·1	1·30
Lime	6·5	16	3·52	23·56	14·73	5·4	. .	7·48
Magnesia	. .	2	. .	. .	. .	. .	. .	. .
Soda	}	8	{9·09	11·45	8·76	. .	10·1	10·55
Potash	}		{ . .	. .	. .	6·4	. .	1·35
Sulphur	. .	trace	0·95	?	3·16	1·0?	2·9	3·96
Water	2·1	trace	0·12	0·35	. .	1·0?	. .	. .
	100·0	92	98·06	98·78	100·00	94·3	100·0	100·00

These analyses show that lapis lazuli is not a mineral of definite constitution, but a mixture, a result which is corroborated by its appearance and physical structure. It

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is, therefore, useless to attempt the calculation of a formula from the analyses. On examining thin slices of the mineral under the microscope, the blue colouring matter is seen to be distributed amidst a white ground. The composition of artificial ultramarine renders it probable that the colouring matter of the natural mineral is either a polysulphide of sodium, or a compound of the protosulphide with a polythionate of sodium.

Lapis lazuli is usually found in granite or in crystalline lime-stones. It is brought chiefly from China, Siberia, and Bucharia; the specimens often contain scales of mica and pyrites. On the banks of the Indus, it occurs disseminated in a greyish limestone.

The richly coloured varieties are highly esteemed for making costly vases and ornamental furniture; it is also employed in the manufacture of mosaics, and when powdered constitutes the rich and durable pigment called ultramarine (*q.v.*)

LAPIS OLLARIS or *Potstone* is a coarse granular dark-coloured variety of steatite.

LARCH. See LARIX.

LARDERELLITE. A borate of ammonium occurring at the lagoons of Tuscany, as a white efflorescence composed of microscopic crystals. It contains, according to Bechi (Sill. Am. J. [2] xvii. 130), 68·55 per cent. boric anhydride, 11·73 oxide of ammonium, and 18·32 water, agreeing nearly with the formula $(NH^4)^2O.4B^2O^3.4H^2O$. It is soluble in water, and the hot solution yields another salt, composed of $(NH^4)^2O.6B^2O^3.9H^2O$.

LARDITE. A variety of talc (*q.v.*); also syn. with AGALMATOLITE.

LARIX EUROPÆA or *Pinus Larix*. The Larch tree. The young branches of this tree exude a kind of manna, from which Berthelot has obtained a fermentable sugar called melezitose (*q.v.*) The bark contains a peculiar acid, to be described in the next article.

LARIXINIC ACID. $C^{16}H^{16}O^8$. (Stenhouse, Phil. Trans., 1863, p. 53; Proc. Roy. Soc. xi. 405.)—A volatile crystallisable acid contained in the bark of the larch-tree, most abundantly in that of the smaller branches of trees from 20 to 30 years old. It is obtained by exhausting the bark with water at 80°, evaporating the extract to a syrup and distilling in vessels of glass, porcelain, or silver. The acid which passes over crystallises, partly on the inner surface of the receiver, but the greater part is obtained in the crystalline form on evaporating the distillate. The brown-yellow crystals thus obtained are purified by recrystallisation and sublimation.

Sublimed larixinic acid forms crystals resembling those of benzoic acid, often an inch long, and having a brilliant silvery lustre; they are monoclinic and usually occur in twins. The crystals deposited from water are also monoclinic. The acid sublimes at 93°, melts at 153°, often volatilises with vapour of water, has a slightly bitter astringent taste, and smells like camphor or naphthalene. The crystals catch fire readily, and burn with a bright flame, leaving no residue. The acid reddens litmus slightly. dissolves in 87·9 pts. *water* at 60°, more easily in boiling water and in *alcohol*, sparingly in *ether*. *Nitric acid* converts it into oxalic acid. When treated with *hydrochloric acid* and *chlorate of potassium* it does not yield chloranil.

The aqueous solution of larixinic acid is precipitated by *baryta-water*, forming an easily decomposible precipitate which contains 34·9 per cent. baryta. The acid is not precipitated by *lime-water* or *sugar-lime*, or by *lead-*, or *silver-salts*; neither does it reduce the metal from the latter on boiling. *Ferric salts* produce, even in dilute solution of larixinic acid, a characteristic purple-red colour.

Larixinate of potassium forms flat red-brown crystals which become darker on recrystallisation, and are decomposed, even by carbonic acid.

Larixinic acid is not found in the bark of *Abies excelsior*, or *Pinus sylvestris*.

LASIONITE. Syn. with WAVELLITE.

LASURITE. Blue carbonate of copper (i. 783).

LASYLIC ACID. $C^7H^8O^2$. An acid whose phenyl-ether, $C^{13}H^{12}O^2 = C^7H^7(C^6H^5)O^2$, is produced, together with hydrochloric acid. by the action of oxychloride of phosphorus in excess on salicylate of sodium. When the temperature rises high, a viscid liquid passes over, which, on standing, deposits tabular crystals of the phenyl-ether, leaving a mother-liquor which smells of hydrate of phenyl. (Kolbe and Lautemann, Ann. Ch. Pharm. cxv. 157.)

LATERITE (from *later*, a brick) is a name applied by Indian geologists to a formation common in Ceylon and India, and consisting of reddish clay, more or less hardened, and enclosing nodules of quartz: the Cingalese call it cabook. True laterite is a hard, dense, almost jasper-like, reddish or brick-red rock, consisting of hardened

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clay enclosing quartz-crystals. A second variety, which is most common in Ceylon, is softer, may be cut with the knife, but hardens on exposure to the air. A third kind is sedimentary or breccia-like, consisting of quartz-nodules loosely embedded in clay, and has been produced by disintegration of true laterite, which appears to be itself a product of the decomposition of granite or gneiss containing hornblende. (Jahresber. 1853, p. 892.)

LATEX. A juice which circulates through plants by means of a set of vessels called the laticiferous tissue or cinenchyma, and coagulates into a gelatinous substance called cambium, which precedes the formation of cells. The descending juice is, according to Frémy, a mixture of several liquids, some of which contain vegetable secretions, while others serve for the development of vegetable organs. In those parts of the vegetable organism which are in process of development, there exists a kind of juice called by Frémy, the *albuminiferous latex*, which closely resembles the young organs in chemical composition, and forms the material for the production of the cambium. Under favourable circumstances, this juice may be obtained tolerably pure by making a slight incision into the growing tissues just below the epidermis. This juice—which is obtained with essentially the same properties from the leaf-stalks of *Colocasia odora*, and the banana tree, the stems of *Stephanotis* and *Tanghinia*, the roots of the arum, and the parenchyma of the gourd—coagulates completely when heated, or on addition of a trace of nitric or tannic acid. It usually exhibits the alkalinity of serum or of egg-albumin; leaves, when dried up, a residue consisting almost wholly of albumin (in fact it is as rich in albumin as blood-serum or milk), and yields ash consisting mainly of alkaline chlorides and carbonates. (Frémy, Compt. rend. li. 647.)

LATHYRUS ANGUSTIFOLIUS. In the seed of this plant, Reinsch found an uncrystallisable bitter substance, vegetable fibre, starch, legumin, vegetable albumin, gum, salts, a fixed oil, a resinous and a waxy substance.

LATROBITE. Syn. with ANORTHITE.

LAUMONTITE. *Laumonite, Lomonite, Efflorescing zeolite.*—A hydrated silicate of calcium and aluminium, occurring in monoclinic crystals, in which the principal axis, orthodiagonal and clinodiagonal are to one another as 0·516 : 1 : 0·8727, and the inclined axes make an angle of 68° 40′. Angle $\infty P : \infty P = 86° 16'$; $oP . (P\infty) = 151° 9'$. Observed planes $oP . \infty P . (\infty P\infty) . +P . -P . -2P\infty$. Cleavage perfect parallel to $\infty P\infty$, also to ∞P. The mineral occurs also in columnar, radiating, or divergent forms. Hardness = 3·5 to 4. Specific gravity = 2·29 to 2·36. Lustre vitreous, inclining to pearly on the cleavage-faces. Colour white, passing into yellow or grey, sometimes red. Streak uncoloured. Transparent or translucent; becomes opaque, and usually pulverulent on exposure. Fracture scarcely observable, uneven. Not very brittle. Before the blowpipe it intumesces and melts to a frothy mass; forms a transparent bead with borax. It gelatinises with nitric or hydrochloric acid, but is not affected by sulphuric acid.

Analyses: *a.* From Phipsburg, State of Maine (Dufrénoy, Ann. Min. [3] viii. 303,—*b.* From Courmayeur, Savoy (Dufrénoy, *ibid.*).—*c.* From Skye (Connel, Edinb J. of Sc. 1829, p. 252).—*d.* From Huelgoet, Bretagne (Malaguti and Durocher, Ann. Min. [4] ix. 325).—*e.* Red variety from Upsala (Berlin, Pogg. Ann. lxxviii. 415).—*f.* From Port George, Nova Scotia (How, Sill. Am. J. [2] xxvi. 30).

	SiO^2	Al^2O^3	Fe^2O^3	CaO	H^2O	
a.	51·98	21·12	. .	11·71	15·05	= 99·86
b.	50·38	21·43	. .	11·14	16·15	= 99·10
c.	52·04	21·14	. .	10·62	14·92	= 98·72
d.	52·47	22·56	. .	9·41	15·56	= 100
e.	51·61	19·06	2·96	12·53	14·02	= 100·18
f.	50·43	21·64	. .	12·07	15·26	= 100·40

These analyses lead to the formula $CaO.Al^2O^3.4SiO^2 + 4H^2O$ (requiring 51·63 SiO^2, 21·51 Al^2O^3, 11·78 CaO, 15·08 H^2O), or $Ca''(Al^2)^{vi}Si^4O^{12}.4H^2O$, which is reducible to that of a hydrated metasilicate, $R^2SiO^3.H^2O$.

Laumontite occurs in the cavities of amygdaloïd, also in porphyry and syenite, and occasionally with calcspar, in veins traversing clay-slate. Its principal localities are in the Faroe Islands, at Diako in Greenland, at Eule in Bohemia, in clay-slate on the St. Gothard, and in large masses in the Fassa valley; at Hartfield Moss in Renfrewshire, accompanying analcime; in the amygdaloïd rocks of the Kilpatrick Hills near Glasgow; and in several trap-rocks of the Hebrides and the north of Ireland. Fine specimens are found at Peter's Point, Nova Scotia; it is also abundant in many places in the copper-veins of Lake Superior, and in several other localities of North America.

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Laumontite is remarkable for the facility with which it gives up its combined water, in consequence of which it is often found opaque and friable. This change may be prevented in cabinet specimens by dipping them in a thin solution of gum-arabic. According to Malaguti and Durocher, it loses 2·26 per cent. water when kept for a month in a vacuum, and 3·65 in the exsiccator over sulphuric acid. In damp air it does not effloresce; and the effloresced mineral, when exposed to such an atmosphere, recovers the water which it has lost.

Sometimes the alteration of laumontite by natural processes goes a step further, and carbonate of calcium is formed. A laumontite from Oberscheld, near Dillenburg, thus altered, contains (dried at 100°), according to Wildenstein (Jahresber. 1850, p. 734),

SiO^2	Al^2O^3	Fe^2O^3	CaO	H^2O	CO^2		
39·12	13·43	2·60	25·18	6·22	13·45	=	100

or, deducting carbonate of calcium:

56·33	19·34	3·73	11·64	8·96	. .	=	100

It has therefore been converted into a mixture of laumontite containing only half of the original quantity of water, with carbonate of calcium and a small quantity of free silica.

Laumontite likewise occurs more or less altered to orthoclase (C. Bischof, *Rammelsberg's Mineralchemie*, p. 631; Lewinstein, *ibid.* p. 997; Jahresber. 1860, p. 771).

Caporcianite (i. 741) is perhaps an altered laumontite.—*Schneiderite*, a zeolite from the gabbro of Tuscany, and containing, according to Bechi (Sill. Am. J. [2] xiv. 64), 47·79 per cent. silver, 19·98 alumina, 16·76 lime, 11·04 magnesia, 1·62 alkali, and 3·41 water, is, according to Breithaupt, a decomposed laumontite. Berlin regards *edelforsite* (ii. 361), and similar minerals from Fahlun and Martenberg in Sweden, as decomposed laumontites.

LAURELIC ACID. An acid obtained, according to Grosourdi (Jahresber. 1851, p. 562), from the berries of *Laurus nobilis* (p. 477).

LAURIC ACID. $C^{12}H^{24}O^2 = \left.\begin{matrix} C^{12}H^{23}O \\ H \end{matrix}\right\}O$. *Laurostearic acid. Pichuric acid.*

(Marsson, Ann. Ch. Pharm. xli. 33.—Sthamer, *ibid.* liii. 393.—Görgey, *ibid.* lxvi. 303.—Heintz, Pogg. Ann. xcii. 429 and 583; J. pr. Chem. lxvi. 1.—A. C. Oudemans, Jun., J. pr. Chem. lxxxi. 356.—Gm. xv. 43.)—This acid, belonging to the series $C^nH^{2n}O^2$, occurs in the fat of the bay-tree, *Laurus nobilis* (Marsson); in the fat of pichurim-beans (Sthamer); also in the volatile oil of these beans (A. Müller, J. pr. Chem. lviii. 469); in small quantity, together with many other acids, in spermaceti (Heintz); in croton-oil (Schlippe, Ann. Ch. Pharm. cv. 14); in the fruit of *Cyclicodaphne sebifera* (Gorkom, Tydschrift af Necrl. Indie, lxxxi. 410); in the so-called Dika bread, the fruit of *Mangifera gabonensis*, together with myristic acid, but unaccompanied by any other acids (Oudemans); in the age or axin of the Mexicans, a salve-like fat obtained from *Coccus Axia* (Hoppe, J. pr. Chem. lxxx. 102); and in cocoa-nut oil (Görgey and Oudemans). It may be formed artificially by heating ethal (cetylic alcohol) with potash-lime to 275°—280° (Heintz, Scharling). According to Heintz, it is produced only from mixed (crude) ethal, inasmuch as this substance contains lethal:

$$C^{32}H^{34}O + KHO = C^{12}H^{23}KO^2 + 2H^2.$$

But, according to Scharling, it is obtained from the ethal itself, $C^{16}H^{34}O$, which, according to him, is decomposed by heating with potash-lime, in such a manner as to yield stearic, palmitic, myristic, lauric, and butyric acids. (Scharling, Ann. Ch. Pharm. xcvi. 236; Heintz, Ann. Ch. Pharm. xcvii. 271.)

Preparation.—1. *From Bay-fat.* Laurostearin from commercial oil of bay (p. 476) is saponified with potash-ley; the soap is separated by common salt, and its hot aqueous solution is decomposed with tartaric acid. The lauric acid then rises to the surface in the form of an oil which solidifies on cooling, and is freed from adhering tartaric acid by repeated fusion with water. (Marsson.)

2. *From Pichurim beans.*—Laurostearin from *Fabæ pichurim maj.* is saponified with potash-ley till a clear soap-jelly is formed; common salt is added, and the white, brittle soda-soap thus produced is dissolved in boiling water, and supersaturated at the boiling heat with hydrochloric acid; lauric acid then rises to the surface as a colourless oil, which on cooling solidifies to a white crystalline mass. It is freed from hydrochloric acid by repeated washing with water, and purified by repeated crystallisation from weak alcohol. (Sthamer.)

3. *From Cocoa-nut oil.*—The oil is saponified with weak potash-ley; the soap

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decomposed by dilute sulphuric acid, and the mixture distilled as long as fatty acids pass over, the water being repeatedly poured back. The distillate neutralised with potash, solidifies on evaporation to a gelatinous soap, which is separated by common salt, repeatedly dissolved in potash and again separated with salt, to free it from the fatty acids which can be thus removed, and again decomposed with dilute sulphuric acid. It is then neutralised with ammonia; the solution precipitated by chloride of barium; the liquid strained off; and the barium-salts which remain repeatedly boiled with water. The resulting solutions, as they run from the funnel, immediately deposit loose flocks of laurate of barium, and the liquid, as it cools down, becomes turbid and deposits pulverulent caprate of barium. (Görgey; see also *Prep.* 5.)

4. *From Spermaceti.*—The saponification of this substance yields, besides ethal, considerable quantities of stearic, palmitic, and myristic acids, and smaller quantities of lauric acid.—The solution of 10 lbs. of purified spermaceti in 30 lbs. alcohol is boiled for some time with 4½ lbs. caustic potash previously dissolved in alcohol; the solution precipitated with aqueous chloride of barium, and strained while hot; the still warm residue pressed as strongly as possible in a warmed press, then well moistened with alcohol and again pressed; the alcohol distilled off from the solutions; the residue freed from the whole of the soluble matter by repeated treatment with ether; and the portion insoluble in ether added to the barium-salts previously obtained. In this manner are obtained, on the one hand, crude ethal; on the other, the barium-salts of the fatty acids of spermaceti.

The barium-salts suspended in water are boiled with very dilute hydrochloric acid, till the supernatant oily layer appears perfectly clear; the fatty acids thus obtained are dissolved in alcohol; the solution is left to cool; and the crystals which separate are pressed, first alone, then several times after being moistened with alcohol; whereby a mixture of palmitic and stearic acids is separated, while a portion of these two acids, and the whole of the myristic and lauric acids, remain in solution.

The whole of the mixed alcoholic solutions are heated; a concentrated aqueous solution of acetate of magnesium is added, so as to precipitate about $\frac{1}{50}$ of the quantity of fatty acids present; the precipitate which forms on cooling is separated by filtration; acetate of magnesium added to the filtrate in about the same quantity as before, and the same treatment repeated (the liberated acetic acid being neutralised towards the end with ammonia), till acetate of magnesium no longer forms any precipitate even in presence of excess of ammonia. In this manner a number of magnesium-salts (19) are obtained, from which stearic, palmitic, and myristic acids may be separated by processes to be hereafter described in connection with these acids.

The alcoholic solution, from which everything precipitable by acetate of magnesium in presence of excess of ammonia has been thus removed, still retains lauric acid, together with myristic and oleic acids. It is precipitated with acetate of lead; the precipitate is washed with dilute alcohol, dried, and freed from a small quantity of oleate of lead, by treatment with ether; and the undissolved portion is decomposed by prolonged and repeated boiling with very dilute hydrochloric acid, whereby a mixture of acids melting at 39·7° is separated. By repeatedly crystallising this mixture from alcohol, as long as the separated acid exhibits a rise of melting point, lauric acid is ultimately obtained, melting at 43·6°, and not capable of further decomposition by partial precipitation with acetate of barium, while myristic acid remains in solution. (Heintz.)

5. From spermaceti or other fats containing lauric acid, provided they are free from oleic acid, or this acid has been removed by the process to be described below.—The fat is saponified with alcoholic potash; the fatty acids are separated from the ethal or the glycerin, as above described, and dissolved in 10 pts. of hot alcohol; the solution is left to cool slowly in a cellar; and the fatty acids which crystallise out are separated by filtration and pressure. The mother-liquor is diluted with an equal quantity of boiling alcohol and supersaturated with ammonia; acetate of magnesium is added in excess to remove a certain portion of the fatty acids; the alcohol distilled off from the filtrate; the remaining salts decomposed by boiling with dilute hydrochloric acid; the separated acids re-dissolved in a quantity of hot alcohol sufficient to retain them in solution after cooling; and a concentrated solution of acetate of barium equal to about $\frac{1}{12}$ of the weight of the fatty acids, is repeatedly added, as long as a precipitate is thereby formed on cooling. The precipitates last obtained, which contain chiefly lauric acid, are separately decomposed by boiling dilute hydrochloric acid, and each portion of acid thereby liberated, whose melting point lies above 43·6 is separately and repeatedly crystallised from dilute alcohol, till its melting point has risen to 43·6. (Heintz.)

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If the fat contains oleic acid, it is saponified, the fatty acid is separated and mixed with a small quantity of hot alcohol, and the solid portions are removed by submitting the cooled mass to pressure The mother-liquor (together with the alcohol used for washing the separated acids) is precipitated with ammonia and neutral acetate of lead; the washed and dried lead-salts are completely freed from oleate of lead by means of ether; the undissolved portion is decomposed by boiling hydrochloric acid; and the separated fatty acids are treated as above (Heintz). In this manner, pure lauric acid is easily obtained from cocoa-nut oil (which, according to Oudemans, does not contain oleic acid). If the acids dissolved in alcohol be precipitated in small portions with acetate of barium, the first portions contain palmitic and myristic acids; and from the remaining liquid, lauric acid may be obtained by repeated fractional precipitation, or by crystallisation in the cold. (Oudemans.)

Properties.—Lauric acid solidifies after fusion to a scaly crystalline mass, exhibiting a laminated texture on the fractured surface; from alcohol, in white, silky needles, united in tufts, or in prickly glandular scales. It melts to a colourless oil at 43·6° (Heintz), 42°–43° (Marsson, Görgey), 43° (Sthamer), 45° (Müller), 43·3° (Schlippe), 43·5 (Oudemans). The alcoholic solution has a slight acid reaction. Specific gravity 0·883 at 20° (Görgey). When boiled with water it volatilises with the vapour. (Görgey, Oudemans.)

It is insoluble in *water*, but dissolves easily in *alcohol* and in *ether*.

By the distillation of its calcium-salt, lauric acid is resolved into laurostearone and carbonate of calcium. (Overbeck):

$$2C^{12}H^{24}O^2 = C^{23}H^{46}O + CO^2 + H^2O.$$

Laurates. Lauric acid is monobasic, the general formula of its salts being $M'C^{12}H^{23}O^2$, and $M''(C^{12}H^{23}O^2)^2$.

The *barium-salt*, $Ba''(C^{12}H^{23}O^2)^2$, is prepared as above described (p. 474), and crystallises on cooling from a boiling saturated aqueous solution in snow-white flakes. The saturated alcoholic solution becomes filled, on cooling, with delicate crystalline spangles, which, after drying at 100°, resemble caprate of barium (Görgey). It is wetted by alcohol and ether, but not by water (Görgey). Dissolves in 10,864 pts. of water at 17·5°, in 1·982 pts. boiling *water*, in 1,468 pts. cold and 211 pts. hot *alcohol* (Görgey). Decomposes before melting. (Heintz.)

The *calcium-salt* is a white precipitate, obtained by mixing the solutions of laurate of sodium and chloride of calcium.

The *lead-salt*, $Pb''(C^{12}H^{23}O^2)^2$, forms a snow-white, loose, amorphous powder (Heintz); *aminæ*, having a beautiful nacreous lustre (Müller). It melts between 110° and 120°, and solidifies to a dull, amorphous mass (Heintz); melts below 100° to a colourless liquid, which solidifies in the crystalline form on cooling (Müller). It is insoluble in *water*; insoluble in cold, sparingly soluble in boiling *alcohol*. (Müller.)

The *copper-salt*, $Cu''(C^{12}H^{23}O^2)^2$, is obtained by precipitating the hot alcoholic solution of the aqueous sodium-salt with aqueous sulphate of copper.

The *silver-salt*, $AgC^{12}H^{23}O^2$, obtained by precipitating the solution of the sodium-salt in weak alcohol with nitrate of silver, is a white powder, consisting of slender microscopic needles (Heintz). It dissolves easily in ammonia, and crystallises from the hot concentrated solution in very small needles (Marsson). It is scarcely or not at all altered by light, but decomposes before fusion when heated. (Heintz.)

The *sodium-salt*, $NaC^{12}H^{23}O^2$, prepared by nearly saturating a boiling solution of pure carbonate of sodium with lauric acid, evaporating over the water-bath, dissolving the remaining soap in alcohol, and evaporating the filtrate to dryness, forms a white powder, whose alcoholic solution solidifies on cooling to a white opaque jelly. The aqueous solution becomes turbid when largely diluted with water.

LAURIC ETHERS. *Laurate of Ethyl*, $C^{12}H^{23}O^2.C^2H^5$, is prepared by passing hydrochloric acid gas into an alcoholic solution of lauric acid, adding water, which separates the ether, washing first with alkaline, then with pure water, and drying over chloride of calcium. It is a colourless oil, having a fruity odour and sickly taste. Specific gravity 0·86 at 20° (Görgey). Crystallises at 10°. Boils at 269°, when the barometer stands at 750 mm. (Delffs); at 264°, with partial decomposition. (Görgey.)

Vapour-density by experiment 8·4; by calculation (2 vol.) = 7·9.

Laurate of Glyceryl, or *Laurostearin*. $C^{37}H^{70}O^6$ [or rather, perhaps, $C^{37}H^{68}O^5 = \left.\begin{matrix}(C^3H^5)'''\\ H.(C^{12}H^{23}O)^2\end{matrix}\right\}O^3$].—This fatty body is found in the berries of the sweet bay-tree (*Laurus nobilis*) (Marsson); also in cocoa-nut oil (Görgey), and in pichurim beans. (Sthamer.)

Preparation.—1. *From the berries of the Bay-tree.*—These berries are treated with

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boiling alcohol; the solution is filtered hot; the crystals of impure laurostearin w separate on cooling are melted over the water-bath; the liquid thus obtained is filt to separate a resinous substance which accompanies it; and the remaining lauroste is purified by repeated crystallisation from alcohol. It is thus obtained perfectly p

2. *From Commercial Oil of Bay.*—The oil is exposed to sunshine on porcelain p covered with glass shades, whereupon the green colour soon disappears, and br hard lumps of laurostearin separate from the mass of fat melted by the sun's h these are separated by filtration, dissolved in alcohol, and obtained of a pure whit evaporation or by precipitation with water. (Bolley.)

3. *From Pichurim beans* (*Fabæ pichurim major.*).—The beans are exhausted with alcohol (which extracts volatile oil, pichurim-camphor, resin, a buttery fat, and a br colouring matter); and the exhausted beans are boiled with alcohol of 81 per c and pressed between hot plates. The expressed liquid, as it cools, deposits pale ye laurostearin, only a small quantity of that substance remaining dissolved in the alc It is purified by washing with cold alcohol, pressure, and recrystallisation from et alcohol. (Sthamer.)

Laurostearin forms white needles having a silky lustre, melting at about 44°, s ingly soluble in cold alcohol, moderately soluble in boiling alcohol, very solubl ether. By dry distillation, it yields acrolein. When treated with alkalis, it is reso into glycerin and lauric acid.

Laurostearin gives by analysis 73·19 to 73·53 per cent. carbon, and 11·45 to 1 hydrogen, agreeing nearly with the formula $C^{57}H^{56}O^{4}$ (calc. 73·97 C, 11·41 H, 14·62 O), according to which, laurostearin contains the elements of 2 at. lauric + 1 at. glycerin − 3 at. water:

$$2C^{12}H^{24}O^{2} + C^{3}H^{8}O^{3} - 3H^{2}O = C^{57}H^{56}O^{4}.$$

This, however, does not agree with the constitution of the normal glycerides (ii. 8 Perhaps, therefore, the true formula may be $C^{57}H^{52}O^{5} = 2C^{12}H^{24}O^{2} + C^{3}H^{8}O^{3} - 2H^{2}$ $\left.\begin{matrix}(C^{3}H^{5})''' \\ C^{12}H^{23}O)^{2} \\ H\end{matrix}\right\}O^{3}$.

LAURIN. *Bay-berry Camphor.*—A substance discovered by Bonastre (J. Pha x. 32) in the berries of the bay-tree, and further examined by Marsson (Ann. Pharm. xli. 329) and Delffs (*ibid.* lxxxviii. 354). It is prepared by boiling skinned and pounded berries with alcohol of 85 to 90 per cent., filtering at the boi heat, and leaving the liquid to itself for several days. Laurostearin is then first de sited; and on filtering again and leaving the liquid to evaporate, laurin is deposited crystals contaminated with a viscid oil, from which they may be freed by press between paper and recrystallisation.

Laurin forms crystals belonging to the dimetric system, destitute of taste and sm insoluble in water, very soluble in alcohol, even in the cold—also in ether. The so tions are neutral to test-papers. Laurin does not dissolve in alkalis.

According to the analysis by Delffs, laurin contains 76·5—77·1 per cent. carbon, a 86·92 hydrogen, numbers agreeing approximately with the formula $C^{22}H^{30}O^{2}$.

Laurin cannot be distilled without decomposition. Its alcoholic solution is precipitated by acetate of lead or nitrate of silver.

LAURONE. $C^{23}H^{46}O = C^{12}H^{23}O.C^{11}H^{23}$? *Laurostearone.*—A substance produ by the dry distillation of laurate of calcium. It crystallises from alcohol in shini plates, which melt at 66°. It becomes electric by friction. Gives by analysis 81 and 81·04 per cent. C, and 13·82—14·10 H, agreeing nearly with the preceding form (81·65 C, 13·61 H, and 4·74 O), which is that of the acetone of lauric acid. (Ov beck, Pogg. Ann. lxxxvi. 591.)

LAUROSTEARIN. See Laurate of Glyceryl (p. 475).

LAURUS CAMPHORA, OIL OF. See i. 729.

LAURUS NOBILIS. The *Sweet Bay-tree.*—The fruit of this tree has be analysed by Grosourdi (J. Chim. méd. [3] vii. 257, 321, 385; Jahresber. 1851, p. 56 He finds that, in the fresh berries, the pericarp constitutes nearly a third of the enti weight; the kernels, freed from episperm, make up more than half the weight of t seed; and the episperm amounts to rather more than $\frac{1}{11}$th of the weight of the fre seed.

100 pts. of the dried berries yielded 0·86 silica, 0·12 carbonate of calcium, 0·12 oxid of iron and manganese. 0·53 carbonate of potassium, 0·07 sulphate of potassium, 0·1 chloride potassium: in all, = 1·75 per cent. ash.

The composition of the entire fresh fruit, pericarp and kernel (cotyledons), is give in the following table:—

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Composition of Bay-berries.

	Pericarp.	Kernel.	Entire Seed.
Water	47·417	39·539	42·216
Starch	. .	37·827	21·929
Lignin	32·860	7·783	20·526
Oil of kernels	. .	5·975	3·377
Oil from pericarp	4·724	. .	1·560
Stearolaurin	0·210	. .	0·068
Stearolauretin	. .	0·180	0·008
Pectin or Pectic acid	2·772	. .	0·888
Resin	2·054	. .	0·663
Phæosin or Phæosic acid	3·318	5·685	5·341
Laurin	. .	1·428	0·853
Uncrystallisable sugar	4·301	1·003	2·080
Lauretin	. .	0·120	0·009
Lauretic acid	0·650	0·360	0·403
Albuminous matter	0·200	0·110	0·320
Colouring matter	1·619	. .	0·488
Volatile oil	0·005	trace	trace
	100·120	100·010	100·729

Laurelic acid was obtained by treating the pericarp with water, precipitating the pectin with alcohol, evaporating the alcoholic liquid, dissolving the residue in water, precipitating the aqueous solution with nitrate of lead, and decomposing the precipitate with sulphydric acid.

Stearolaurin (? identical with laurostearin) is the solid fat which gradually separates at 10° from the warm-pressed oil of the pericarp.—*Phæosin* or *Phæosic acid* is a brown substance extracted by carbonate of sodium from the pericarp, exhausted successively with water, alcohol, and ether.

LAVA. See Volcanic Products.

LAVENDER, OIL OF. Lavender (*Lavandula Spica*, L.) yields a yellowish volatile oil, having a strong but agreeable odour, and an acrid aromatic taste. It reddens litmus, and contains, in variable proportions, a crystalline substance having the composition of common camphor (Dumas). The liquid portion of the oil appears to be mainly composed of two substances, one of which has the composition of oil of turpentine. (Gerhardt, *Traité*, iv. 336.)

LAVENDULAN. An amorphous mineral from Annaberg in Saxony, which appears to be an arsenate of cobalt, mixed with the arsenates of nickel and copper. It has a greasy lustre, inclining to vitreous. Hardness = 2·5 to 3. Specific gravity = 3·014. Colour lavender-blue. Streak paler blue. Translucent. Fracture conchoïdal. Melts easily before the blowpipe, colouring the flame blue, and becoming crystalline on cooling. (Breithaupt, J. pr. Chem. x. 505.)

LAZULITE. *Azurite. Azure-stone. Blue Spar. Voraulite. Klaprothin.*—A hydrated phosphate of aluminium, magnesium, and iron, occurring in monoclinic pyramids, with truncated summits and several secondary faces. The inclined axes make an angle of 88° 15′; and the principal axes, orthodiagonal and clinodiagonal, are to one another as 0·86904 : 1 : 1·0260. Angle $\infty P : \infty P = 91° 30'$; $oP : P\infty = 139° 45'$. Observed faces, $+2P\infty$, $-2P\infty$, $-2P$, oP, $+2P$, $-P$, and others. Twin-crystals also occur with face of composition $\infty P\infty$. Cleavage lateral, indistinct. The mineral also occurs massive.

Hardness = 5 to 6. Specific gravity = 3·057 (Fuchs); 3·067 to 3·121 (Prüfer); 3·122 (Smith and Brush). Lustre vitreous. Colour azure-blue, commonly of a fine deep blue when viewed along one axis, and a pale greenish-blue along another.

When heated in a tube, it gives off water and turns white. Before the blowpipe, it colours the flame faint green, swells up, becomes tumid, but does not melt; gives a fine blue colour with cobalt solution.

Analyses.—*a.* Light blue from Krieglach in Styria: mean of two analyses (Rammelsberg, *Mineralchemie*, p. 340).—*b.* Light blue from near Werfen in Saltzburg (Fuchs, Schw. J. xxiv. 373).—*c.* Dark blue from the Fischbach Alp in Styria: mean of two analyses (Rammelsberg, *loc. cit.*).—*d.* Dark blue from Sinclair County, North Carolina (Smith and Brush, Sill. Am. J. [2] xvi. 365).

	P^2O^5	Al^2O^3	MgO	FeO	CaO	H^2O		
a.	44·16	33·14	12·52	1·77	1·53	6·88	=	100
b.	42·70	36·50	9·54	2·70	. .	6·19	=	97·63
c.	42·58	32·89	9·27	8·11	1·11	6·04	=	100
d.	43·76	31·70	10·01	8·17	. .	5·59	=	99·26

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From these numbers Rammelsberg deduces the formula, $[3(Mg;Fe)''O.P^2O^5 + 3Al^2O^3.P^2O^5 + 3H^2O$. The darker varieties contain a larger proportion of iron than the lighter varieties.

Lazulite occurs in narrow veins traversing clay-slate, in the torrent beds of Schladming and Rädelgraben, near Werfen in Saltzburg, and the other localities above mentioned; also at Tijuco in Minas Geraes, Brazil. It is abundant at Crowder's Mount, Lincoln County, North Carolina. (Dana, li. 405.)

LEAD. Synonyms: *Blei; Plomb; Plumbum; Saturnum.* Symbol, Pb. Atomic weight, 207.

This metal does not often occur in nature in the metallic state; but of all the substances in which it is recorded to have been found native, the most trustworthy are those in which it was discovered among volcanic products.

The colour of lead is bluish-grey; and when it is cut, the fresh surface has considerable lustre; but this brilliancy disappears in a short time, in consequence of the formation of a thin crust of suboxide.

The lead of commerce is nearly pure, as shown by the analyses given at p. 504; the impurities, often present in very small quantities, are silver, copper, antimony, and sometimes iron and manganese.

Lead is very soft, is easily cut by a knife, and may be scratched by the nail. It readily receives impressions, and leaves a streak on white paper. It is very malleable and ductile, and is capable of being rolled into thin sheets or drawn into wire. It occupies the sixth rank among metals as to malleability, and the eighth rank as to ductility. Rolled lead is more ductile than cast lead, in the proportion of 7 to 5. Its malleability and ductility are much affected by the presence of impurities, especially by the oxide of lead, which it dissolves in small quantities in the melted state.

It is very deficient in tenacity; a wire $\frac{1}{12}$ of an inch in diameter does not support 20 lbs. In this respect, rolled and cast lead are precisely alike; but with the latter the fracture takes place at once, and the ends are clean and granular.

Lead begins to melt at 325° C., and is completely fused at 335° C. (635° F.); at a red heat, it gives off vapours. At a temperature of 50° P., it loses ·005 of its weight in a charcoal-lined crucible, which increases to ·09 as the heat rises to 150° P., whereas galena loses 3·71 per cent.

It crystallises in regular octahedrons. Mongez obtained it in four-sided pyramids by slow cooling; and Marx procured it in fern-like forms, similar to those in which sal-ammoniac crystallises, by allowing a considerable quantity of melted lead to cool until half had solidified, then piercing the crust and running off the fluid portion. By the electro-chemical action of zinc in a solution of acetate of lead, it is deposited in an arborescent form, known under the name of *Saturn's Tree*. Landrin states that, in 1826, he noticed, in a deep mine in Cornwall, cubical crystals of lead which had been deposited on the miner's tools, and had been entirely oxidised. The presence of silver interferes with the crystallisation.

Lead emits a dull sound when struck with a hammer; but when cast in the form of a mushroom, it becomes sonorous.

The specific gravity of lead is, according to Kupffer, 11·3305; Brisson and Herapath, 11·352; Morveau, 11·358; Karsten, 11·3888; according to Berzelius, when in a state of purity, 11·445.

Its specific heat, according to Cooke, is 0·031400. It is an inferior conductor of heat and electricity.

Lead is pyrophoric in a state of fine division. It is usually obtained in this state by heating tartrate of lead in a glass tube as long as any fumes are evolved, when the tube is sealed by a blowpipe. On breaking the tube after cooling, and scattering the powder in the air, it will burn with a red flash.

When lead is melted in contact with the air, the surface is rapidly coated with an iridescent pellicle, which then passes into a yellow oxide. When the temperature is high enough to melt the oxide, it is absorbed by the lead, which loses its lustre and ductility: it becomes brittle, and all the faces of the fracture are dull. It recovers all its original properties by refusion with charcoal.

The action of air and water on lead has been carefully studied by Prof. Miller, from whose account of their combined action we give the following particulars:—This metal undergoes no change in a perfectly dry atmosphere, nor when sealed up in contact with pure water from which the air has been expelled by boiling. It is, however, subject to a powerful corrosion when exposed to the combined action of air and *pure* water. The surface of the lead then becomes oxidised, the water dissolves the oxide, and this solution absorbs carbonic acid, when a film of hydrated carbonate of lead, $2PbHO.Pb^3CO$, is deposited in silky scales. Another portion of oxide is formed, which is dissolved by the water, and thus a rapid corrosion of the metal ensues. This action is materially modified when various salts exist in the water, even when their quantity does not

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exceed 3 or 4 grains in the gallon. The corrosion is increased by the presence of chlorides and nitrates, but diminished by sulphates, phosphates, and carbonates, the oxide of lead being scarcely soluble in water containing these salts in solution. Acid carbonate of lime is remarkable for its preservative influence; and in consequence of the presence of this salt in most spring waters, they do not act on lead to any serious extent, a film of carbonate of lead being deposited on the surface of the metal, and protecting it from further action.

The action of *water* on lead is very important in a sanitary point of view, as this metal is so constantly employed in making cisterns, pipes, &c. for domestic purposes. Rain-water from the roofs of houses, especially in towns, is sufficiently impure to prevent its action on the metal. The most insoluble salt of lead is the hydrated oxycarbonate (p. 478) which is only soluble to the extent of abont 1 pt. in 4 millions or one-sixtieth of a grain per gallon of water. When a solution of lead is exposed to the air, silky crystals of this hydrated oxycarbonate are formed, and in a few hours the water does not contain more than $\frac{1}{4,000,000}$ of lead in solution. Water, however, which contains much carbonic acid in solution, is very dangerous, as it dissolves the carbonate of lead. When such water is boiled, the carbonic acid escapes, and the carbonate is deposited. Water has generally so much action on lead, that slate cisterns are much safer than those made with lead.

The *non-oxidising acids* do not act upon lead, except when in contact with the air, as already explained in the case of carbonic acid. *Nitric acid* easily acts on lead, even in the cold, forming protoxide, which is then dissolved. Strong *sulphuric acid* converts the lead into sulphate, when the acid is heated to the boiling point. *Hydrochloric acid* has little or no action, but aqua regia converts the lead into chloride. When *arsenic* or *arsenious acid* is heated with lead, arsenite and arsenide of the metal are formed.

Lead is readily oxidised by *cupric oxide*, which is at the same time reduced to the state of cuprous oxide: it also partially reduces the cuprous oxide, but the oxide of lead which is formed retains a portion of the oxide of copper in combination and prevents any further action on the metallic lead.

Nitre acts rapidly on lead at a high temperature, forming a fusible compound of protoxide of lead and potash. The *acid sulphates* also oxidise this metal; but the neutral sulphates and the alkaline carbonates have no action.

Sulphur, *selenium*, *phosphorus*, and *arsenic* combine directly with lead.

Lead also alloys with most of the *metals*; but only imperfectly with copper, titanium, uranium, cerium, cobalt, nickel, and iron.

Extraction of Lead.

Historical Notices. The most abundant and valuable ores of lead possess so many properties likely to attract the attention of uncivilised nations, that it is not surprising to find early mention of this metal. Some authorities think that allusion is made to its metallurgy in the Hebrew word *opher*, in reference to the powder produced by the formation of the oxide on molten lead. The earliest mention of lead is in the well-known passage in the Book of Job; and it is again named as one of the spoils taken from the Midianites in the Book of Numbers. It is also probable that galena was used as a glaze for earthenware in the time of Solomon, from the notice in Proverbs xxvi. It was also one of the articles in which the Phœnicians traded, and which they may have obtained, in part at least, from this country. It was used in the hanging gardens of Babylon, the level of each terrace being covered with sheets of solid lead.

The Romans also worked the ores of this metal both in Spain and in this country. In the former country, the extent of the Carthaginian mining and smelting operations excite our surprise in the present day, and the slags left by them have been re-smelted on a large scale within the last twenty years, while lead cast in Roman moulds—*pigs*, in fact, of the age of Hadrian and other emperors—have been found in Flintshire, Yorkshire, and other localities.

The methods of obtaining the lead from its ores have not undergone any great change, the smelters having adopted the reverberatory or blast furnace as they found the one or the other more suited to the character of the ores of each locality. The one great improvement in the metallurgic treatment of this metal is Pattinson's desilverising plan, which has been followed by the softening process for the hard leads of commerce, especially those of Spain; and we may remark that the only other addition to the ancient methods has been the condensation of the lead fume.

The Ores of Lead. Lead is seldom found native, but there are upwards of twenty ores of this metal known to the mineralogist. Those of practical importance, however, are very few in number, and all the lead of commerce may be said to be

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procured from five minerals, viz. the carbonate, sulphate, phosphate, arsenate and the sulphide, the latter ore furnishing more of this metal than all the others.

Sulphide of Lead, or *Galena*, is found in the older and more recent strata, and more or less, in every country of the globe. It occurs in veins in the killas of Cornwall, and in the mountain limestones of Derbyshire and the northern counties. In Cardiganshire and Montgomeryshire, it occurs in the strata of the lower Silurian rocks; and the chief deposits of the United States are found in the rocks of the same geological age. It fills veins in gneiss in Saxony; at Sala in Sweden, it is found in granular limestone.

Analyses of Galena.

Locality .	*Lauenstein, Hanover.*	*Przibram, Bohemm.*		*England.*	*Inverkeithing, Scotland.*
Analyst .	Westrumb.	Lerch.		Thomson.	Robertson.
Lead . .	83·00	81·80	83·61	85·13	84·63
Silver . .	0·08				
Iron . .	. .	. .	. .	0·50	
Zinc . .	. .	3·59	2·18		
Sulphur . .	16·41	14·41	14·18	13·02	13·21
	99·49	99·80	99·97	98·65	97·84

Sulphide of lead occurs also, in combination with the sulphides of antimony and copper, in the minerals *Geocronite*, *Boulangerite*, *Jamesonite*, *Bournonite*.

Carbonate of Lead, or *Cerusite*, occurs in crystals, and in fibrous, compact, and earthy masses. It is frequently found in lodes, and sometimes in beds in sedimentary limestone, generally associated with galena. It is worked in quantity near Aix-la-Chapelle, and in the neighbourhood of Santander in Spain. It is also found in the mines of Cornwall and Devonshire, in Yorkshire, at Leadhills in Anglesey, and at Seven-Churches in Wicklow.

Analyses of Cerusite.

Locality . . .	*Leadhills, Scotland.*	*Nertschinsk.*	*Griesberg, in the Eifel.*	*Oberlahnstein, Nassau.*
Analyst . . .	Klaproth.	John.	Bergemann.	Wildenstein.
Oxide of lead . .	82	81·4	83·51	83·64
Oxide of iron . .	. .	. .	. .	. .
Clay	. .	. .	. .	. .
Water	. .	. .	. .	. .
Carbonic acid . .	16	15·5	16·49	16·36
	98	96·9	100·00	100·00

Locality . . .	*Benkhausen, Westphalia.*	*Phœnixville, Pennsylvania.*	*Vannes, France.*	*Teesdale, England.*
Analyst . . .	Schnabel.	Smith.	Berthier.	Phillips.
Oxide of lead . .	83·93	84·76	66·0	83·50
Oxide of iron . .	. .	. .	2·3	
Clay	. .	. .	15·3	
Water	. .	. .	2·2	
Carbonic acid . .	16·07	16·38	13·0	16·50
	100·00	101·14	98·8	100·00

Carbonate of lead is also found, with other salts of lead and copper, in the minerals *Cromfordite*, *Susannite*, *Lavarkite*, *Calcedonite*.

Sulphate of Lead, or *Anglesite*, is found in cavities, but more generally in lodes associated with galena and carbonate of lead. It occurs at Leadhills in Scotland, in Cornwall and Derbyshire; in the Channel Islands; in Spain, Germany, France, and America.

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The composition of this mineral is given in the following analyses:

Locality .	*Anglesey.*	*Wanlockhead, Lead Hills.*	*Zellerfeld, Hartz.*
Analyst .	Klaproth.		Stromeyer.
Oxide of lead . .	71·0	70·50	72·46
Oxide of iron . .	1·0	. .	0·09
Oxide of manganese .	. .	. .	0·06
Water	2·0	2·25	0·51
Sulphuric acid . .	24·8	25·75	26·09
	98·8	98·50	99·21

Sulphate of lead also occurs combined with other salts, in the form of *Linarite, Caledonite, Leadhillite.*

Phosphate of Lead, or *Pyromorphite*, occurs generally at the upper parts of lodes, less frequently in layers, and also usually associated with other ores of lead. There are three classes of this ore, viz. such as contain only phosphoric acid; secondly, those containing both phosphoric and arsenic acids; and lastly, those containing lime and fluorine.

The composition of some of the ores of the first class, is given in the following Table:

Locality .	*Leadhills.*	*Poullaouen.*	*Kransberg.*	*Berezov.*
Analyst .	Wohler.	Karsten.	Sandberger.	Struve.
Chlorine . .	2·52	2·53	2·67	2·54
Lead . . .	7·39	7·56	7·80	7·40
Oxide of lead . .	74·50	74·15	73·22	73·36
Phosphoric acid .	15·59	15·76	15·94	15·82
Oxides of iron and chromium .	. .	. .	. .	0·59
	100·00	100·00	99·63	99·71

This ore is found at Leadhills, and in Cornwall; at Wicklow in Ireland; at Phœnixville, in the United States; and many other localities.

Arsenate of Lead or *Mimetesite* is met with in large quantities at Drygill, in Cumberland, and has been used in the manufacture of flint glass, to which it imparts great brilliancy. It is found at Redruth and other Cornish mines; at Beeralston in Devonshire, and in America, Siberia, &c., generally occurring near the outcrop of the veins. There are three classes of it, similar to those of the previous ore. The following is the composition of a specimen of the ore which contains arsenic acid, analysed by Bergemann:

	From Blanca, Mexico.
Oxide of lead	74·96
Arsenic acid	23·06
Chlorine	2·44
	100·46

The other ores of lead will be found described in these volumes under their respective mineralogical designations.

Metallurgical Treatment of the Ores of Lead. The differences in the nature of the ores of lead, the peculiarities of the localities as to labour, fuel, &c., and the application of the lead afterwards, have all tended to modify the metallurgy of this valuable metal. It would have been more satisfactory to have described all the different plans in detail; but as this would be inconsistent with the limited space which can be devoted to a metallurgical subject in these volumes, we must confine this article to an account of some of the methods adopted for extracting lead from its ores. Various arrangements might also be pursued in this account of the smelting of lead ores, but we prefer the following, in which we will describe—I. Reduction of the Ores. II. Refining of the Lead. III. Softening of Hard Lead. IV. Smelting of the Slags and other Products. V. Condensation of the Lead Fume.

I. Reduction of Lead Ores.

All the ores of lead may be arranged in two classes in respect to their metallurgical treatment, viz. the sulphur and oxygen compounds of lead, and again as to the form of furnaces employed in their reduction, viz. the reverberatory and the blast furnace.

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1. The Reduction of Sulphur Ores in Reverberatory Furnaces.

The sulphur ores of lead are treated after two different systems in the reverberator furnace, which have been distinguished by Phillips as the *method of double decompos tion* and the *process by affinity*, and these again differ in the details as practised i this country, in France, and in Germany.

The first plan depends upon the reaction between sulphide of lead and oxide of lea as shown in the following equation:

$$PbS + 2PbO = 3Pb + SO^2;$$

or upon the double decomposition when sulphide and sulphate of lead are the const tuents of the mixture, thus:

$$PbS + PbSO^4 = 2Pb + 2SO^2.$$

This process consists in roasting the galena in a reverberatory furnace, until portion of the ore has been converted into oxide and sulphate of lead; it m be performed either in a distinct furnace, or in the smelting furnace where the subs quent fusion is effected. The following table of analyses of roasted ores, from differe localities, illustrates the above remarks.

Analyses of Roasted Galena.

Locality .	*Pezey.*	*Holzapfel.*		*Pontgibaud.*		
Oxide of lead . .	18	35	31·0	52·6	16·9	62·9
Sulphate of lead . .	86	19	8·0	8·0	12·1	
Sulphide of lead . .	10	4	11·8			
Oxide of iron . .	. .	6	9·0	13·0	21·3	4·9
„ zinc . .	. .	27	30·2	9·0	21·6	3·7
„ manganese .	. .	2				
„ antimony .						
„ copper . .						
Arsenic acid . .	. .	. .	. .	0·4	1·0	
Sulphate of baryta .	. .	. .	. .	14·0	19·8	0·7
Silica	. .	7	10·0	3·0	6·2	23·9
Lime, &c. . . .	. .	. .	. .	. .	. .	3·1
	114	100	100·0	100·0	98·9	99·2

When the roasted ore has been thoroughly mixed, the doors are closed and the fires a set away. The reactions above explained then take place, when the lead is separate This process is applicable to the ores which are comparatively free from silica an earthy impurities, and is generally adopted in England.

The process by affinity consists in fusing the ore with iron in some form or othe when, the iron combining with the sulphur, the lead is eliminated: thus,

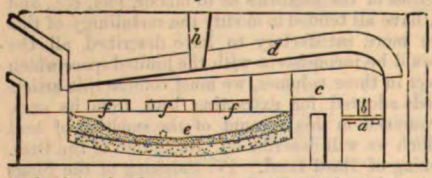
$$PbS + Fe = Pb + FeS;$$

and this plan is better suited to the impure ores of lead.

a. *Method by double Decomposition.*

English Process.—*The Reverberatory Furnace* consists, as usual, of three essenti parts, the fireplace, hearth and chimney. The position and relative proportions of eac part are shown in *figs.* 589 and 59 where *a* represents the grate; *b*, th door of the fireplace; *c*, the fir bridge; *d*, the arched roof; *e*, th hearth; *f f*, the working doors; *g* flues running into one main flu leading to a condensing-chambe and chimney.

Fig. 589.

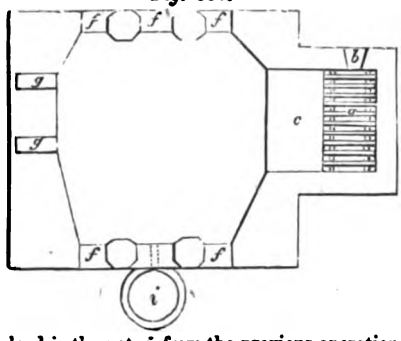


The hearth is hollow or funnel shaped, to facilitate the descent o the lead to the lowest point in the bed of the furnace. The bottom of these furnaces or hearth, as it is called, is built of bricks, which are covered with a layer of slags These slags are run into a semi-fluid condition by a heavy fire, and then worked int the proper shape by means of paddles and rakes. The hearth slopes more rapidly fro the fire-bridge than from the flue, to prevent the lead being exposed too long to th action of the heated air.

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There are three working doors on each side of the furnace, attended by two men, who assist each other in manipulating the charge. The lead collects at the lowest part of the hearth, covered by the slags, and is drawn off by a *tap-hole* into the metal pot, *i*, in front of the furnace.

Fig. 590.



The arch falls rather rapidly towards the flues, *g g*, to give more effect to the heat, and the draught is capable of regulation by means of dampers.

The usual charge of ore in these furnaces at Holywell weighs 20 cwt., which is introduced through a hopper, *h*, in the arch of the furnace. This charge is then spread evenly over the surface of the earth, and gently heated for two hours, the doors being closed and the damper lowered.

The two front doors, farthest from the fire, being opened, the smelter throws in the slags swimming on the surface of the lead in the pot, *i*, from the previous operation. The tap-hole is opened in a little time to allow the metallic lead to run off from the slags, and at the same time, an assistant turns over the ore, through the back doors, by means of a paddle. These doors are now closed, while the front ones are open, through which some small coal is thrown in upon the lead-bath, and the whole is worked up together, the ore being turned over with a paddle. The smelter, in about three-quarters of an hour from the commencement, throws back upon the sole of the hearth, the fresh slags, which then float upon the bath, and are mixed with the coaly matter. These slags and the ore are then turned over with the paddle, and all the doors are closed.

The ore is turned over again through the back doors, and the first lead appears, obtained from the slag last remelted. This lead is run off by the tap, and both workmen then turn over the ore, through all the doors. The smelter now closes all the front doors except that next the fire-bridge, and lifts off the fresh slags from the lead pot, drains them, and throws them back into the furnace. The interior of the furnace, at this period, has a dull red heat.

The lead begins to separate from the ore in about 1½ hour from the charging of the furnace, and the two workmen again turn over the ore from each side of the furnace. Some coal is thrown on the grates, slightly to raise the heat, the ore is turned over, and all the doors are closed.

The *first fire* or roasting lasts about two hours, and the damper is then raised a little; coal is thrown on the grates to give the *second fire*, which lasts 25 minutes. The heat of the furnace has now become bright red, and the lead flows from all sides to the bath. The smelter then pushes the slags back towards the upper part of the hearth, while the assistant spreads them over its surface, through the back doors. The smelter now throws in a few shovelfuls of quicklime upon the lead-bath, through the middle door. The assistant works the ore and slags through the three back doors, spreading them out, while the smelter again pushes the slags from the inner bath to the upper part of the sole. The doors are left open for a short time, and the lead flows down into the basin from the slags with which it was mixed as they were pushed back.

The workmen in a short time again turn over the ore and slags, and in three hours from the commencement, a little more fuel is thrown on the grate. In ten minutes, fresh fuel is added for the *third fire*, the damper is fully raised, all the doors are again closed, and the furnace is left in this state for three-quarters of an hour. At the expiration of about four hours, all the doors being opened, the assistant levels the surface to facilitate the separation of any lead, and then spreads the slags which are pushed back towards him by the smelter, who now throws in more lime to render the slags less fluid and to cover the lead-bath.

The smelter adds a fresh charge of fuel in about ten minutes after the completion of the third fire, and closes the doors to give the *fourth fire*. This fire is finished in four hours and forty minutes, when the doors are opened, the tap-hole is pierced to allow the lead to flow into the pot outside, and some lime is thrown upon the slags in the inner bath. The smelter then pushes these *dried* slags towards the upper part of the hearth, whence the assistant rakes them out of the furnace through the back doors.

We have given this detailed account of the working of a charge from Mr. Phillips' excellent description of the process followed in Wales, as an illustration of the nature of these operations, and to avoid the necessity of similar minute details in other analogous processes.

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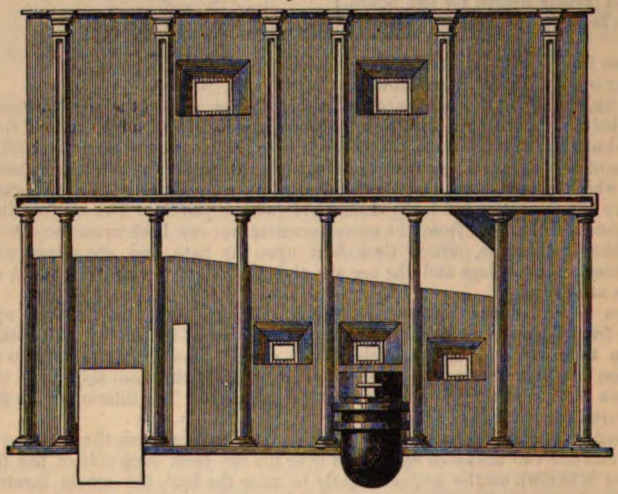
The weight of a charge varies in different localities, 12 to 14 cwt. being that used i the north of England; 21 cwt. in Bristol, and 30 cwt. in Cornwall, while the tin extends from 6 to 24 hours, according to the weight and nature of the ore.

The cost of smelting an average parcel of galena in the reverberatory furnace is:

	s.	d.	
Labour	9	7·2	per ton of ore.
Coals 19·9 cwt. . . .	3	3·8	„
Lime 0·9	0	4·9	„
Repairs	0	4·0	„
	13	7·9	

In some smelting works, the roasting process is conducted in a distinct furnace, a in other mills, the two furnaces are combined in the manner shown in *fig.* 591, whi

Fig. 591.



represents the front or tapping side of the furnace. It is unnecessary to give a details of this form, after the description of the previous furnace.

When the process of roasting is conducted in a separate furnace, as a distinct oper tion, the cost per ton, from an average of upwards of 700 tons, is as follows:

	s.	d.
Labour	3	2·5
Coals 5·6 cwt. . .	0	11·2
Repairs . . .	0	1 8
	4	3·5

This is probably the most suitable place to notice the results of some experimen made by Plattner and other chemists, on the loss of silver which occurs during t roasting of ores containing this metal, and which we can confirm from our own experien

1. The loss of silver arises from chemical reactions.

2. The volatilisation of the silver appears to take place at the moment when passes into the metallic state from its combination with sulphur, or when the sulpha of silver is decomposed.

3. The loss of this metal increases with the duration of the roasting, and the rise the temperature.

4. The loss also increases when the oxides of iron or copper are present to deco pose the sulphate of silver.

5. The loss is not so great with the silver-compounds of arsenic and antimonic acid obviously because these salts are not so soon decomposed as the sulphate of silver.

We may also here notice the proposal of Fallizé, to tap the lead at different period instead of doing so at the end of the operation. He founds his proposal on the fa that the lead which is first reduced, is the richest in silver; and by keeping the differe products distinct, the subsequent operation of desilverising would be to some exte anticipated as well as facilitated, by providing leads varying in their richness in silve

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well worthy of adoption, as we have found the
fall from 74 oz. to 44 oz. silver per ton, according
ected.

lena containing silver has also been made. The
t. of chloride of lead, and 10 per cent. of common
is said the galena will be desilverised, and the
rface with the common salt. The mixture of the
h any chloride of lead that may be present. We
al results of this process, having found the loss of
y chloride of lead was present.

employed in this process differs from the English,

n, and *fig.* 593 a horizontal section. Two furnaces
one chimney. The hearth of these furnaces is

Fig. 592.

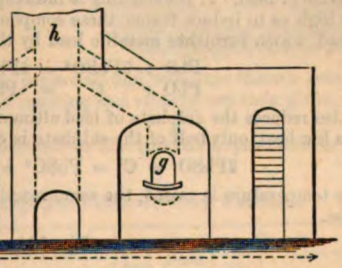
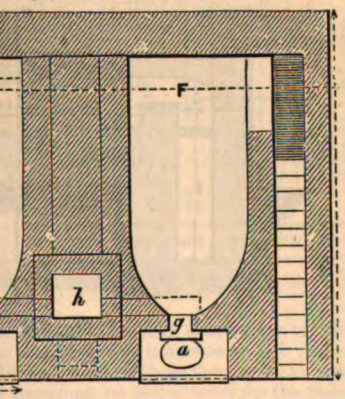


Fig. 593.



re-bridge to the flue; and is so arranged that the
pot *a*, outside the furnace. The hearth is formed
ne of beaten clay, and the upper of fused slags,
in an opposite direction, and at its highest point,
fireplace is shown by the dotted lines *ppp*, and
over the hearth, escape to the chimney *h*, through
cent furnaces of this form, the hearths are con-
eration being completed in the lower hearth.

e wood of the spruce and pine, and the charge of
king lasts 23 hours, and the produce is very large.
shed and treated again. The lead flows into the
ion, and then cast into pigs.

anation of the reactions on which this Carinthia

out gradually increasing heat, a portion of the sul-
ead, along with some oxide of lead, while part of

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When the temperature is raised, during the vigorous stirring of the ore, a quanti of lead is liberated, as already explained. Some subsulphide of lead is, however, a formed, which likewise reacts with the sulphate of lead, producing metallic lead; th

$$Pb^2S + PbSO^4 = 3Pb + 2SO^2.$$

During this first period of the operation, lead is continuously liberated, and runs do to the bath in the hearth. The progress of the roasting converts more and more of t sulphide into sulphate of lead, diminishing the liberation of lead until a point reached, when oxide of lead is the only product of the reaction; thus,

$$PbS + 3PbSO^4 = 4PbO + 4SO^2.$$

The second stage of the operation is then in progress, when, by the addition of red-h charcoal and an increased temperature, the litharge is reduced and another portion lead is obtained.

French Process.—When galena is exposed to a continuous and slowly increasi temperature, a large proportion is converted into sulphate of lead, and a smaller p tion into oxide of lead. If the roasting is interrupted at this point and the heat rais but not so high as to induce fusion, these compounds react upon each other, produci oxide of lead, which furnishes metallic lead by the reducing action of coal; thus,

$$PbS + 3PbSO^4 = 4PbO + 4SO^2$$
$$PbO + C = Pb + CO.$$

The coal also reduces the sulphate of lead ultimately into metallic lead and sulphur acid. At a low heat, only half of the sulphate is converted into sulphide of lead; th

$$2PbSO^4 + C^2 = PbSO^4 + PbS + 2CO^2.$$

And as the temperature is raised, the same reaction occurs, as explained in the Car thia process.

Fig. 594.

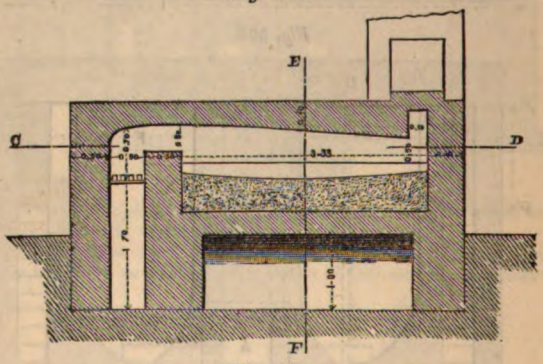
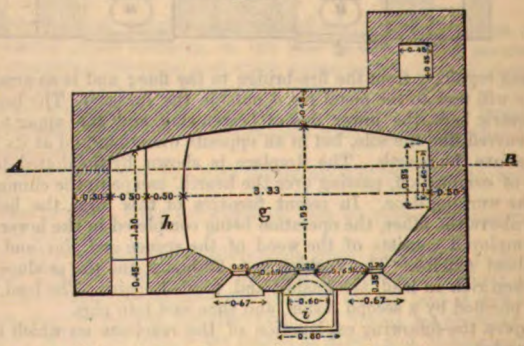


Fig. 595.

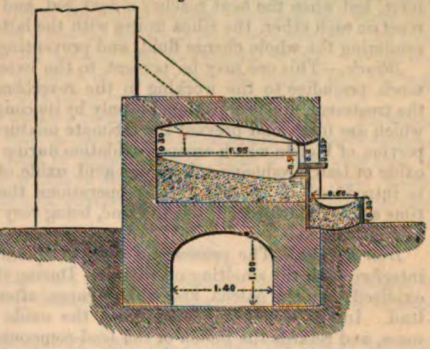


The French process is founded on these reactions, and the furnace employed is r presented by *figs.* 594, 595, 596, the first being a longitudinal, the second a horizont and the third a transverse section.

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her on the same side, and in front of the middle firebridge *h* is 23 inches wide, and the hearth *g*,

Fig. 596.



some coal and wood are thrown into the furnace, roasting and stirring are then given, and the slags

ined in the preceding processes is given in the

gs from Reverberatory Furnaces.

ullaouen.		Birmingham.	Katzenthal.	Grassington.	Lea, near Matlock.			
29·5	35·6	29·4	27·6					
2·5	·4	15·6	11·0	34·0				
64·5	42·0	13·4	26·2	3·0	4·5	2·0	15·4	5·6
1·0	20·8	. .	3·4	. .		2·0	7·2	8·0
. .	. .	. .	4·6					
. .	. .	28·4	. .	. .	8·0	8·0	16·0	14·7
2·5	1·0	5·7	1·6					
. .	. .	5·5	4·0	. .	. .	. .	17·0	2·0
. .	. .	. .	. .	. .	22·0	9·0	12·0	30·0
. .	. .	. .	. .	10·5	22·5	33·0	1·6	5·6
. .	. .	. .	. .	51·0	25·0	30·0	22·0	24·4
. .	. .	. .	. .	1·5	16·0	13·6	7·2	8·5
. .	. .	. .	15·0					
. .	. .	. .	4·6					
100·0	99·8	98·0	98·0	100·0	98·0	97·6	98·4	98·7

vith beams of wood and repeated skimmings, after

es of lead contain more or less of other earthy and considerable influence on the chemical reactions ing. When these foreign bodies are present in a scribed are not adapted for the treatment of such hods to be hereafter explained. It will, however, the influence which these gangues exert on these

ubstance is present in small quantities, it facilitates o the decomposition of the sulphide of lead, with d by preventing the materials becoming too fluid ant reactions are taking place. It has been found ce may be present in the ore without being preju-

ce remains perfectly inert during the whole oper- ole therefore only as a mechanical hindrance, by unds of lead which are to act on each other in 15 per cent. of this gangue are, on this account, atory furnace.

similar in its action to the carbonate of calcium, with sulphate of barium, towards which substance

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Quartz, Clay, and Silicates.—These gangues, when present only to the extent of 5 6 per cent., are very injurious, and it is impossible to obtain any lead in the rev beratory furnace, when they amount to 12 per cent. During the roasting they s inert, but when the heat reaches a dark red, and before the sulphide and oxide of le react on each other, the silica unites with the latter, forming very fusible basic silicat rendering the whole charge fluid, and preventing any further action.

Blende.—This ore may be present to the extent of 10 or even 15 per cent. withc much prejudice to the working in the reverberatory furnace. It does not complic the treatment, and is objectionable only by its conversion into oxide and sulphate of zi which are inert, and prevent the intimate mixture of the lead-compounds. The sm portion of blende which escapes oxidation during the roasting, reacts afterwards on t oxide of lead, producing sulphurous acid, oxide of zinc, and metallic lead. When c is introduced in the subsequent operations, the oxide of zinc is reduced at the sa time as the oxide of lead, and the zinc, being very volatile, carries off a considerable p tion of lead.

Iron Pyrites.—The presence of a small quantity of this mineral does not seriou interfere with the smelting operations. During the roasting, the pyrites is more rapid oxidised than the galena, and what escapes, afterwards assists in reducing the oxide lead. In the concluding operations, the oxide of iron is disseminated through t mass, and retards the fusion of the lead-compounds. A large proportion of pyrites however, very prejudicial, as that portion which is unoxidised, forms a very fusib matt with the sulphide of lead, which escapes the reduction.

When the pyrites is arsenical, the lead is always rendered more or less impure the presence of arsenic, which increases the loss of both lead and silver in the subs quent cupellation.

Sulphide of Antimony.—This ore is always very injurious, even when present on to the extent of 2 or 3 per cent. It gives rise to the same reactions as galena; and portion of the antimony being brought to the metallic state, combines with the lea rendering the latter hard, and occasioning a loss of both lead and silver when submitt to cupellation. The compounds of antimony also form very fusible compounds wi those of lead, which cannot then be brought to the metallic state. The great volatili of antimony, its oxide and sulphide, also increases the loss of lead and silver.

Copper Pyrites.—This mineral renders the ores unfit for treatment in the reverberato furnace. Even when it is present in such small quantities as not to interfere with t reactions, the lead always retains a portion of the copper, which diminishes its co mercial value.

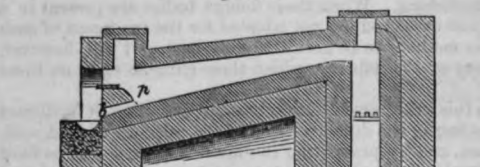
Carbonate of Iron.—This substance acts only as a mechanical hindrance in the fu nace, where it is gradually converted into oxide of iron. During the later period of t operations, it retards the fusion of the slags, and postpones the reactions until near all the sulphide of lead is oxidised. This gangue therefore, when present in sm quantities, is favourable rather than otherwise in the reverberatory furnace.

b. *Process by Affinity.*

This plan was used in France for treating a Spanish galena which contained a lar proportion of quartz, and is founded on the reactions already explained.

The furnace employed is shown in *fig.* 597, and is charged with about 800 lbs. ore through a side door. Th charge is mixed with 200 240 lbs. of iron, which oug to be in the form of scrap iro as cast iron, mill cinder, a iron ores are not found to a swer equally well with small able iron. The mixed char is then rapidly heated unt the galena begins to softe when the temperature is ke stationary to permit the r actions to take place. Th lead, as it is reduced, flows to the lower part of the furnace at *p*, while the matt swi on the surface, and this again is covered by the slag. The contents are then drawn o through the tap-hole *b*, into the metal pot.

Fig. 597.



A modification of this plan has been proposed by Phillips and Rivot, who employ furnace with a hearth slightly inclined towards a basin at the side, placed before on of the two side doors.

The furnace is to be charged with 1600 lbs. of ore, which must be carefully spre

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12 hours at a moderate heat. At this point, if the ica, 12 per cent of sand and 1½ per cent. of charcoal rought up to a cherry-red, when the charcoal reduces he action of the sand, which decomposes the sulphate, rge passes through a process of boiling, and when this wn in while the charge is being well worked; the iron oducing metallic lead and silicate of iron. When the the contents of the furnace are tapped into the pot, lags flow off at one side.

ced another modification of this principle. He mixes nd adds a small quantity of alkali and carbonaceous to heat in large crucibles, when a very pure lead is der, which is afterwards mixed with a little water, is, as a substitute for sulphur ores, in the manufacture

ion of Oxygen-ores of Lead.

ore of lead contains a large proportion of galena, it lready described, but when tolerably pure, it is sub-

reverberatory character, in which the hearth has only p-hole at one of the sides. The ore, in the form of a ucing agent, such as coal, and some flux adapted to charge is then spread upon the hearth, the doors are raised, during which the mixture is often turned over. possible, and the lead, gradually reduced, falls down is drawn off from time to time.

pear, the spongy mass on the hearth, is heated until out and smelted in a blast furnace.

lead is found native, and large quantities are also other manufactories. In the latter case, it is often acid, which must be expelled in a reverberatory or

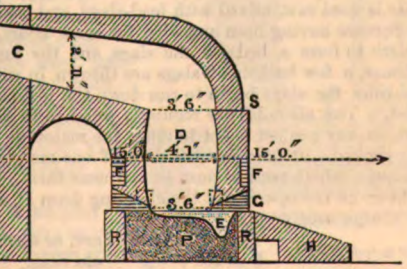
compound of lead is that proposed by Phillips and reader.

furnace, or *Horno de gran tiro*.

—600, does not differ from the blast furnace in its entirely upon the chimney, it may be said, in this re- ory furnace, and finds its appropriate position in this

ameter varies from 3½ feet to 4 feet. The charging

Fig. 598.

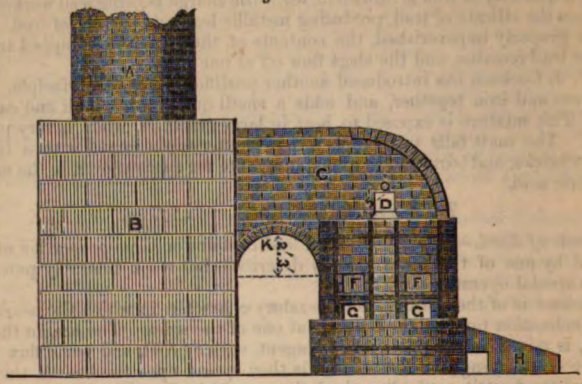


e spring of the arch, S. The sole of the furnace, P, is rial called *Laguena*, a species of decomposed argilla- eat abundance near Cartagena. It is ground to fine o in powder, in the proportion of 3 to 1. This mixture efully beaten with rammers. The walls, R, are also

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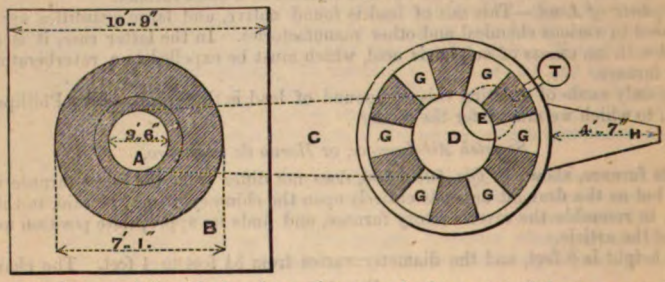
built of the slate in its undecomposed state, called *Laja*. The hearth or crucible then cut out to the shape shown in *fig.* 598. Six openings (*figs.* 599, 600) G G, are in the walls for the admission of the air, and for drawing off the slags. The flue connecting the furnace and chimney, is carried by an arch, K, and is built so as to

Fig. 599.



independent of the furnace. The chimney, A, is about 44 feet high, has a large a and works two furnaces. The air-holes are 15 inches by 12 inches at the outside, taper to 9 inches by 4 inches next the interior. They are formed by working some

Fig. 600.



upon a wooden mandril, and placed to point towards the centre of the furnace. T are also other holes (register), F, above the air-holes, but temporarily built up, s to be easily opened when required. An inclined plane, H, is built to draw away slag, as in an iron blast furnace, and it is kept cool by an air-channel below. The is collected in a small pot, T, through an opening cut through the sole to the hear

The ore smelted in these furnaces contains carbonate of lead and galena, mixed oxide and carbonate of iron, oxide of antimony, carbonate of lime, clay and sa This ore is used raw, mixed with lead-slags, and coke is the fuel employed.

The furnace having been annealed for some hours, 3 or 4 pigs of lead are place the hearth to form a bed for the slags, and the furnace is charged with coke. or 6 hours, a few baskets of slags are thrown in with a little granulated iron. A a little time, the slags begin to run down the incline, when the regular charge of is added. The air-holes are regularly watched to keep them all at the same de of heat, as any neglect is apt to allow the materials to harden, when these air-tuy become choked. It is in fact the duty of one man to remove all the *niggers* or black lumps, which tend to form in and near them. The furnace is charged only every hour, as the opening of the charging door, D, injures the draught.

The charge consists of:

	40 baskets of ore, or about 5 cwt.	
8 to 10	„	old Slag.
4 to 5	„	coke, with some dry wood.

The latter assists in diffusing the air uniformly through the materials. The quant used in 24 hours are:

Ore	cwt. 134	Coke	cwt. 20
Slag . . .	44	Wood	„ 2

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As the air has a tendency to ascend round the sides of the furnace, the smelter throws his charges against the walls, and keeps the air-channels as far as possible open to the centre of the furnace. When the furnace becomes *gobbed* in any part, one or more of the register-holes are opened to enable the smelter to remove the obstruction.

The lead is tapped every six hours, and the matt is returned to the furnace. The produce varies from 6 to 7 cwt. of lead upwards, according to the richness of the ore.

We have described this furnace at some length, as it is cheaply built, lasts about 6 to 8 weeks, and can be used in localities where more perfect plans would be impracticable.

2. The Reduction of Lead Ores in Blast Furnaces.

The ores generally smelted in blast furnaces are such as, from the proportion of their impurities, are not adapted to the reverberatory furnace; but this remark does not apply to the peculiar form of blast furnace known under the name of the ore-hearth, as used in America and this country (p. 497).

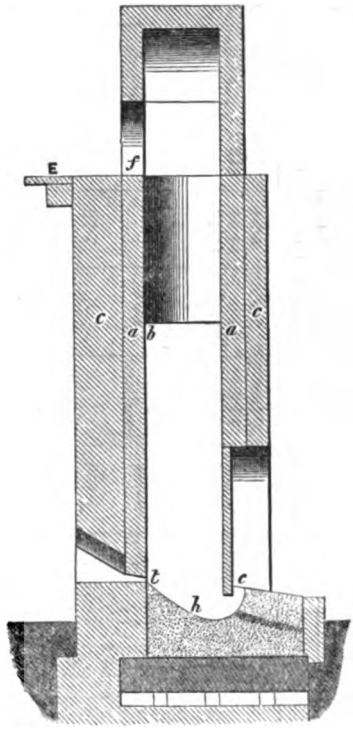
a. *The Cupola or Blast Furnace.*

This form of furnace is very generally adopted on the Continent, and exhibits at different works a great variety of form and dimensions. The great difference in the ores, the fluxes available and the nature of the fuel, are all so many conditions which require special modifications to overcome the difficulties peculiar to each locality.

We will select, as illustrations of this mode of smelting, three of the modifications in which the ore is used in the raw and roasted form, and in both states.

Silesian Furnace.— The form and construction of this furnace are represented in *fig.* 601. The walls, *a a*, are vertical from the tuyere upward; for a distance of 10 feet 4 inches to 6 feet, the section of the furnace is rectangular, while above this point it takes a circular form. The exterior wall, *c c*, is built of common bricks, and the lining or *skirt*, *a*, is constructed of fire-bricks. The charge of raw ore and flux is mixed on the floor, E, and thrown into the furnace through the opening *f*. The blast enters at *t*, and fusion takes place, during which the hearth, *h*, is gradually filled with the lead produced. The slag floats on the surface of the lead, and is drawn off at *c*, while the lead is occasionally tapped through a canal which passes to the bottom of the hearth. The fume is carried away from the top of the furnace through a series of condensing chambers. These furnaces can only be worked for about eight days, when the operation is stopped to repair the lining.

Fig. 601.



The *lit de fusion* consists of:

Galena in small pieces . .	100 parts.
Cast iron	12 ,,
Slag from iron forge . .	14 ,,

Each ton of this charge requires a ton of coal, which is thrown against the front, and the ore, &c. against the back of the furnace.

When the slag contains 7 or 8 per cent. of lead it is resmelted. The matt or regulus, consisting of sulphide of iron and lead, with a little silver, is roasted and smelted in the same furnace.

Harts Furnace.—This plan is adopted in the Hartz, France, and Belgium, more or less modified according to the circumstances of the locality. The ore is always submitted to previous roasting; and when this operation is performed in a reverberatory furnace, the heat is gradually raised, until the oxidation is sufficiently advanced, when the doors are closed. The fire is then urged to melt the mass of materials, which is then drawn, allowed to cool, and broken up into pieces fit for charging the blast furnace.

The following tables contain numerous analyses of the matt and slags which are obtained from the blast furnaces of France and Germany.

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TABLE I.—*Analyses of Matts.*

a. From the Ordinary Process of Smelting Roasted Ores.

Locality	Freiberg.		Muldner.	Halsbrücke.	Antonshütte.	Oker.	Pontgibaud.		Pesey.	Villefort.	Poullaouen.		Holzapfel.		Emser.
Authority	Lampadius.		Plattner.	Ihle.	Kersten.	Ulrich.	Rivot.	Berthier.							
Lead	15·2	25·130	21·816	24·80	9·8	8·64	79·5	5·0	91·5	51·6	85·5	3·5	62·0	49·0	19·0
Iron	1·5	33·120	37·202	15·20	44·0	44·34	12·2	54·6	1·5	24·5	0·9	64·0	2·2	3·3	26·0
Copper	2·1	12·100	12·944	36·20	27·8	17·43	. .	. .	. .	3·0	3·2	0·8	18·6	27·0	17·0
Silver	0·1	0·201	0·099	0·16	1·7 + zinc										
Nickel	35·5	. .	0·544	2·64 and zinc	4·4										
Cobalt	12·4														
Zinc	. .	. .	1·439	. .	. .	7·76	1·1	. .	. .	1·0	. .	. .	trace	2·3	
Bismuth	18·7														
Arsenic	10·3	2·450	0·731	. .	1·1	. .	+ antv 4·2	16·8							
Sulphur	3·0	19·526	22·847	21·00	11·2	19·64	2·3	23·6	5·0	16·6	10·4	31·6	17·2	18·4	27·5
Antimony	. .	4·753	0·718	. .	. .	2·19	. .	. .	. .	1·7	. .	. .	. .	. .	10·5
Earths	. .	. .	. .	. .	. .		. .	. .	2·0	0·6					
	98·8	97·280	98·340	100·00	100·0	100·00	99·3	100·0	100·0	99·0	100·0	99·9	100·0	100·0	100·0

TABLE II.—*Analyses of Matts.*

b. From the Treatment of the Unroasted Ores with Iron.

Locality	All from the Upper Harts.													
Lead	73·346	63·0	41·50	13·65	8·26	52·27	36·0	59·33	53·31	65·78	60·69	63·787	35·68	61·71
Iron	9·814	19·0	34·05	63·14	58·00	28·32	33·2	19·60	21·56	13·03	20·36	13·721	31·55	17·91
Copper	0·396	0·2	0·36	0·88	0·90	1·42	trace	1·10	0·23	1·15	0·49	1·533	3·79	0·77
Zinc	0·198	. .	. .	. .	. .	1·56	2·5	0·17	2·24	0·67	0·55	2·263	. .	1·30
Antimony	0·397	. .	0·66	0·13	2·40	0·31	5·3	0·13	0·38	0·18	0·36	. .	1·49	
Silver	0·116	. .	0·12	0 03	0·02									
Sulphur	15·338	17·5	23·82	22·01	31·38	16·12	22·0	18·92	19·33	17·27	16·40	18·706	23·97	18·13
Manganese	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	0·25	0·18
Arsenic														
Carbon	trace													
	99·605	99·7	100·51	99·84	100·06	100·00	99·0	99·25	97·05	98·08	98·86	100·000	96·73	100·00

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Magnesia	1·24	1·3	0·78	0·75	0·58	1·09	0·62	1·21	0·97	0·33	1·15	0·62	0·18	1·71	1·42
Oxide of lead	5·30	4·2	6·32	7·80	3·98	4·79	7·25	12·31	14·13	4·31	2·06	1·68	2·46	1·62	37·71
Teroxide of antimony	. .	. .	. .	0·50	0·22	. .	. .	0·21	0·27						
Protosulphide of iron	. .	. .	. .	. .	1·71	3·16	1·58								
Sulphide of zinc	. .	. .	. .	. .	1·50	. .	3·60								
Oxide of zinc	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	19·20
Sulphuric acid	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	5·04
Baryta	. .	. .	. .	. .	. .	. .	. .	. .	. .	traces	1·09	0·94	traces		
Molybdic acid	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	0·46
Protoxide of copper	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	traces
Suboxide of copper	. .	. .	. .	. .	. .	. .	. .	0·33	0·34						
Potash	. .	. .	. .	. .	.	. .	. .	2·34	3·80	. .	. .	. .	.	. .	traces
Soda	. .	. .	. .	. .	. .	. .	. .	0·54	0·68	. .	. .	. .	. .	. .	traces
Arsenious acid	. .	. .	. .	.	. .	. .	. .	0·26	0·30						
Sesquioxide of iron	. .	. .	. .	.	. .	. .	. .	. .	. .	. .	. .	. .	. .	.	19·50
	99·22	101·4	98·78	100·81	97·66	100·69	98·41	98·12	97·08	98·66	99·20	97·70	99·53	99·99	99·21

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Analyses of Lead-slags from Blast Furnaces.

(*b.*) From Roasted Ores.

Locality	Freiberg.							Sala (Sweden).	Oker, Unterharz.	Pontg baud
Authority	Lampadius.	Merbach.	Kersten.	Erdmann.	Amburger.	Lampadius.		Bredberg.	G. Ulrich.	Rivot
Silicic acid	28·54	28·00	30·50	37·30	43·26	30·7	28·5	39·39	27·66	39·
Alumina	5·40	4·50	5·10	8·15	. .	3·7	5·4	6·23	6·00	1·
Sesquioxide of iron	. .	. .	. .	. .	5·62					
Protoxide of iron	46·10	49·89	55·74	40·92	46·95	45·0	46·1	17·18	50·30	21·
Protoxide of manganese	. .	. .	2·20	. .	. .	. .	. .	. .	traces	
Lime	8·31	. .	. .	2·66	. .	5·3	8·3	17·77	7·72	11·
Baryta	1·00	. .	. .	. .	. .	1·0	1·0	. .	. .	26·
Magnesia	traces	2·00	. .	3·00	0·45	. .	. .	19 13	1·90	2·
Oxide of lead	4·12	6·05	4·00	7·17	2·00	6·3	4·1	. .	2·13	18·
Oxide of zinc	3·00	. .	0·85	. .	1·91	4·0	3·1	. .	3·50	1·
Protoxide of copper	traces	6·74	. .	. .	0·25	. .	. .	. .	traces	
Sulphuric acid	2·43	2·25	. .	. .	. .	1·0	2·5	. .	. .	1·
Sulphur	1·00	. .	. .	. .	1·26	. .	. .	. .	2·23	
Protosulphide of iron										
Phosphoric acid										
	99 90	99·43	98·39	99·20	101·70	99·0	99·0	99·70	101·44	121·

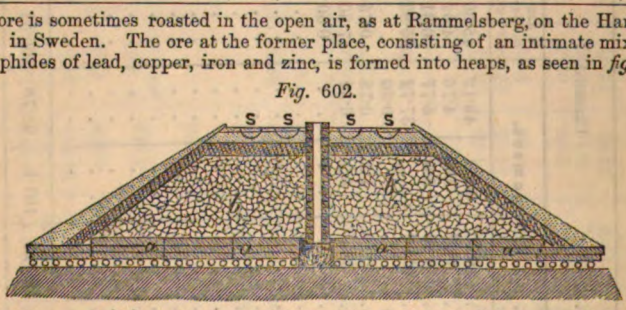
Analyses of Lead-slags from Blast Furnaces—continued.

(*b.*) From Roasted Ores.

Locality	Pontgibaud.		Pezey, Savoy.	Ems.	Holzapfel.	Villefort.	Katzenthal.	Schemnitz, Hungary
Authority	Rivot.		Berthier.					Wehrle.
Silicic acid	40·0	38·0	27·0	48·8	23·2	25·0	40·5	29·8	28·5
Alumina	1·7	1·4	7·6	14·0	3·4	1·3	3·8	1·4	6·0
Sesquioxide of iron									
Protoxide of iron	18·7	19·2	32·0	10·0	34·8	21·5	27·0	59·4	34·5
Protoxide of manganese	. .	. .	. .	. .	7·0	8·0	. .	3·6	
Lime	15·0	24·1	13·0	15·3	6·6	4·2	11·7		
Baryta	3·2	3·3	. .	1·0	. .	. .	7·6	. .	5·60
Magnesia	3·2	2·9	. .	. .	0·6	1·0	. .	. .	1·30
Oxide of lead	13·1	6·0	18·6	9·3	2·0	2·0	8·8	traces	17·7
Oxide of zinc	1·5	1·6	. .	. .	6·8	29·0	. .	. .	4·4
Protoxide of copper	. .	. .	. .	. .	2·4	1·0	. .	. .	1·2
Sulphuric acid	2·3	2·1							
Sulphur									
Protosulphide of iron	. .	. .	. .	. .	12·0	4·0	. .	. .	4·80
Phosphoric acid	. .	. .	. .	. .	. .	. .	. .	0·8	
	98·7	98·6	98·2	98·4	98·8	100·0	99·4	95·0	104·0

The ore is sometimes roasted in the open air, as at Rammelsberg, on the Hartz, a Fahlun in Sweden. The ore at the former place, consisting of an intimate mixture the sulphides of lead, copper, iron and zinc, is formed into heaps, as seen in *fig.* 602

Fig. 602.



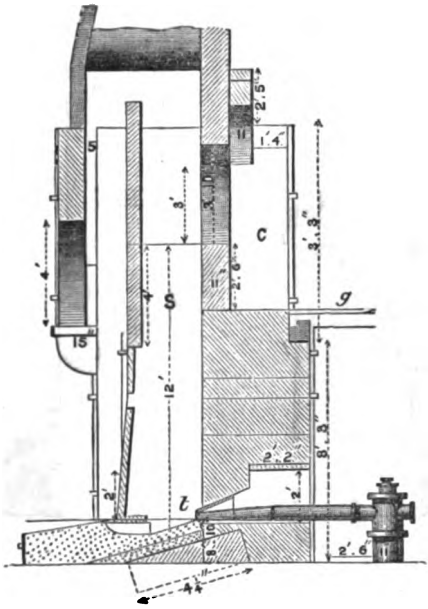
A thick layer of pine wood, *a a a*, is laid down for a foundation, upon which the o *b b*, is placed in pieces decreasing in size towards the top. The whole is covered wi a layer of roasted ore in powder, which shuts off the access of an excess of air. The heaps contain about 150 tons of ore, and after they are ignited, the combustion is su ported by the sulphides, through a period varying from 18 to 24 weeks.

At the top of the pile are a number of cavities, *s s s*, formed in the porous coverin in which a portion of sulphur collects, as it is sublimed from below, and from whi it is ladled at times. A ton of sulphur is usually obtained from a heap, and it is sa nearly to pay the cost of roasting. The metallic products are afterwards roasted in second and third heap.

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This roasted ore is smelted in a furnace constructed as shown in *fig.* 603. The charge is prepared on the floor, *g*, and thrown into the furnace, *s*, through the opening *c*, along with the fuel. A strong blast is driven in through the tuyere, *t*.

Fig. 603.



The charge consists of

Roasted ore	35	cwt.
Highly siliceous slags	10	,,
Oxide of lead and pieces old cupels .	¼–½	,,

The matt is repeatedly roasted and resmelted to obtain any copper, lead and silver, it may contain.

Spanish Economic Furnace. The discovery of enormous deposits of slags left by the Romans, near Cartagena and other places in Spain, together with the mining of a poor lead ore in these districts, has led, within the last 15 or 20 years, to a very great development of lead smelting on this coast. Furnaces of different descriptions were tried, one after another, but they have all given place to what is known under the above name.

This furnace, as improved by the writer, is represented in *figs.* 604, 605, 606, in elevation, section and plan. The blast enters through three water-tuyeres, *a a a*, and the materials are maintained up to the level of the charging door, *b*. The upper layers are kept cool by a fine rain of water from a rose, *c*, and the steam which is formed assists in condensing the fumes which escape into the flue, through an opening, *d*, in the back side of the top of the furnace. The upper part of the furnace rests upon four metal pillars, *ffff*, so that when the body of the furnace requires to be renewed, this part remains untouched. The lead accumulates in the hearth, *g*, whence it is tapped, from time to time, into the pot, *h*, to be ladled into moulds. The slag runs continuously into a tank, *i*, which is kept supplied with a stream of water. The slag in this case falls into a coarse sand, which is easily carted away, but it is sometimes run into small waggons, forming large blocks on cooling.

The furnace is circular, with a diameter of from 2¼ to 2½ feet, and built of fire-bricks moulded to suit the form of the furnace. The body of the furnace is only one brick thick, and when any portion of the wall gives way, the hole is filled with clay, which is driven into the interior, while the smelter lays fresh bricks to rebuild the wall.

The bottom of the furnace is formed in Spain of a kind of clay which is found to answer remarkably well, but in this country a mixture of pure ground coke and fire-

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clay is employed. This mixture, made into a paste, is very carefully beaten down, then the hearth is cut out, as shown in the figure (605). The formation of this bo

Fig. 604.

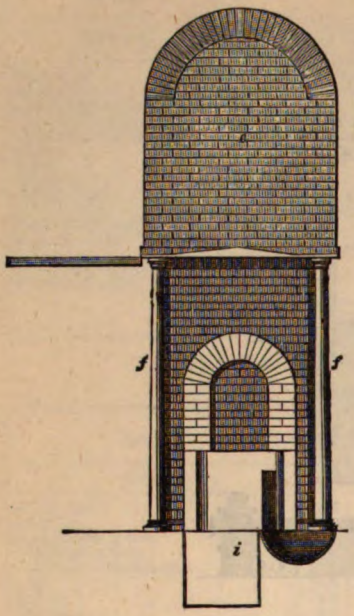


Fig. 605.

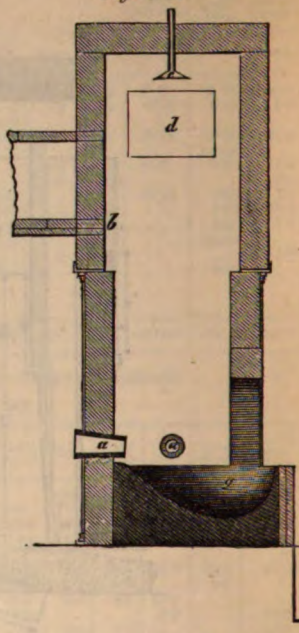
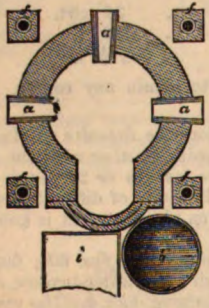


Fig. 606.



requires the greatest care, as the duration o furnace depends more upon its stability than the continuance of the walls, which, as alr explained, can be repaired from the outside.

The breast of the furnace is made of a s circular plate of cast iron, with a lip to carr the slag, and a slit through which the tapho drilled. Above the breast-pan is an arch a 18 inches wide and 24 in height.

The materials are charged, layer upon l of ore and flux and coke. The ore may be ei raw or roasted, and the nature of the flux pends upon the character of the gangue. In S the ore is sometimes roasted in kilns, consis of large chambers, something like our fire-b kilns. The ores or materials containing lea be smelted in this furnace should not hold r than 20 or 30 per cent. of lead.

When this form of furnace was introduced into this country, the writer made a g number of experiments as to the ores and fluxes which could be most profitably sme by it; but it would be impossible to give the details in so limited an article as present. It may, however, possess some interest to give the materials smelted the cost of one of the first campaigns, which term is employed to designate the t the furnace works without being rebuilt. This campaign lasted 15 weeks, work night and day, and the following weights of ores were smelted:

Spanish ore . . .	3249·50 cwt.	English lead ore slags .	1521·25 cw
English lead ores .	8634·60 „	Litharge . . .	30·50 „
American silver ores .	86·75 „	Litharge cinders . .	973·75 „
			14496·35

There was a gain of silver on the assays, but a loss of lead of about one-tenth on

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assays, which, however, it is proper to say, were made most carefully by the best methods. The cost was as follows:

							per ton. s.	d.
1. Wages connected with the furnace					£124	1 9	= 3	5·1
2. Engine power: wages		£10	10	1				
1509 cwt. coals		12	11	6	23	1 7	= 0	7·5
	cwt.							
3. Fluxes, Fluor spar	228½	9	15	0				
Carbonate of baryta	14	1	2	6				
Chalk	209½	0	16	2				
Limestone	250	3	13	0				
Rock-salt	144½	6	11	8				
Kelp	5	0	10	0				
Hematite ore	25	0	18	9				
Metal borings	790	79	15	0				
Mill cinder	4673	40	18	3				
Grey slags	704	1	15	9				
Pitch	5	0	1	3				
Coal	19	0	3	2	= 146	0 6	= 4	0·3
4. Fuel—Coke	2667				47	16 1	= 1	3·8
5. Repairs					33	1 0	= 0	10·9
					£374	0 11	= 10	3·6

The following statement contains the cost of smelting the Roman slags near Cartagena, in Spain, calculated on the produce of lead:

Cost of 20 cwt. of Lead.

360 quintals at 8 per cent. lead, washed up to 24 per cent.

= 120 quintals for smelting		360 reals
30 „ of coal for engine, at 6 reals		180 „
50 „ of coke for smelting, at 11 reals		550 „
2 smelters, at 8 reals		16 „
4 labourers, at 6 reals		24 „
Wear and tear		50 „
Management, &c. &c.		100 „
		1280 reals

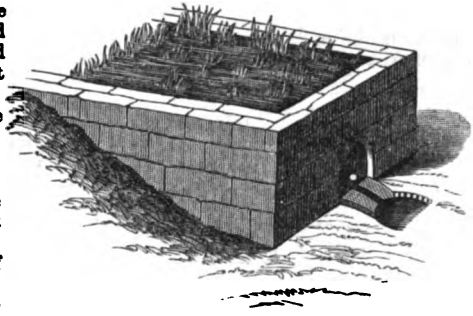
and this expense, at 92 reals per £ sterling, brings the cost of a ton of lead up to £13 6*s.* 8*d.* per ton, where the Roman slags are obtained free of charge.

We believe this form of furnace is admirably adapted for many of our poorer ores and materials containing lead, and that it well deserves the attention of our smelters.

b. *The Ore-hearth.*

This method of reducing can only be applied to the purest description of ores, and the advantage which it possesses over the reverberatory furnace, consists chiefly in the greater purity of the lead which is produced. This, however, is of great commercial importance, as such lead is suitable for conversion into the best white and red leads, and in consequence brings £1 per ton more in the market than ordinary soft lead. The ore hearth is also worked with less consumption of fuel and a smaller outlay in labour. The cost of the furnace is much less and the working may be discontinued and resumed at any time without repairs being required.

Fig. 607.



The first construction to be noticed is that of

The Backwoods Hearth.

This form of furnace is of the most primitive character, and yet the practice of the Western backwoodsman is still more simple; if he wants shot or bullets, he kindles a fire in a hollow tree, or an old stump of a tree, places some galena on the charred wood, and melts it down, when after cooling, he finds the metal at the bottom of the hollow.

In Missouri, the ore was reduced in square furnaces, constructed of logs or stones, as shown in *fig.* 607.

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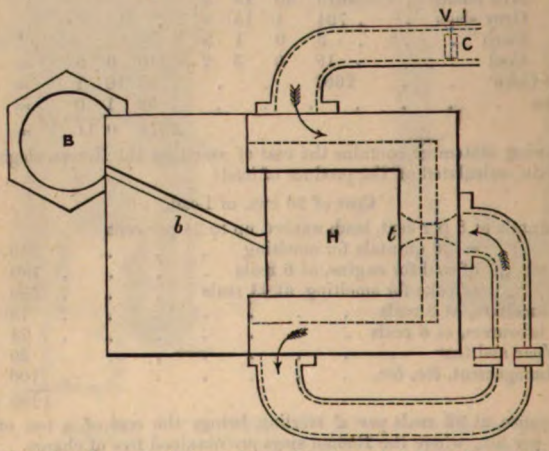
The air is admitted through the arch in the fore-side, and the lead is collected in basin in front. The management consists in placing a layer of heavy logs at bottom; then billets of split wood are set upright, on which the galena is thrown, top of the ore being covered with small wood. A fire is kindled in the front a which chars the lower portion of the wood, and the process of reduction commen The lead runs into the basin, and the operation lasts 24 hours. The ashes are colle after the furnace cools, and they are smelted in what is called an *ash-furnace.*

This plan is now superseded by constructions of a modern type.

The American Hearth.

This furnace (*fig.* 608) is sometimes made of cast iron, and so arranged that a hollow surrounds the hearth, H, through which the air passes on its way to the tuyere, by wh contrivance the blast is raised to a high temperature. The air enters through the p C, and, following the course of the arrows, is driven through the tuyere into the hea

Fig. 608.



As the ore is reduced, the lead flows down the channel, *b*, into the pot, B. The f of the blast can be regulated by the valve, V.

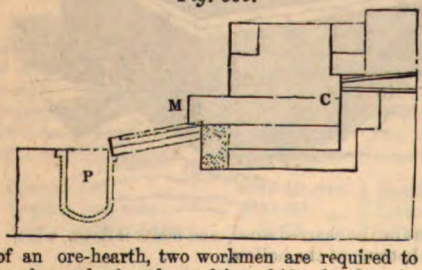
The hearth is first carefully warmed by a wood fire, when the reservoir in the hea H, is filled with lead, which soon melts, and upon which the charge floats during operation. The smelter places several pieces of wood before the blast, and then cha with raw galena. The whole soon becomes heated, the reduction follows, and lead flows off into B. The first charge is followed by another, and thus the proce continued as long as the smelter wishes.

At Rossie, in New York, 75 cwt. of lead is obtained in 24 hours, and the cos working is about seven shillings per ton.

The Scotch Hearth

is in use in the northern counties of this country, and Mr. Phillips' account of mode of working it, is so admirable that we cannot do better then quote it.

Fig. 609.



This furnace (*fig.* 609) is f 22 to 24 inches in height, and 1 18 inches area inside, but its h zontal section, always rectangu varies much in its dimensions different levels.

The ore can be worked eithe a raw or roasted state, but the la is now generally used, as it yiel better produce, and works dry, lowing the blast to diffuse itself n perfectly through the mass.

In proceeding to smelt by me of an ore-hearth, two workmen are required to be in attendance from the beginn to the end of each smelting shift, the duration of which is from 12 to 15 ho The first step in commencing a smelting shift is to fill up the hearth-bottom

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space below the workstone with peats, placing one already kindled before the nozzle of the bellows. The powerful blast very soon sets the whole in a blaze, and by the addition of small quantities of coal at intervals, a body of fire is obtained, filling the hearth. Roasted ore is now put upon the surface of the fire, between the forestone and pipestone, which immediately becomes red-hot and reduced, the lead from it sinking down and collecting in the hearth-bottom. Other portions of ore, of from 10 or 12 lbs. each, are introduced from time to time, and the contents of the hearth are stirred and kept open, being occasionally drawn out and examined upon the workstone, until the hearth-bottom becomes full of lead. The hearth may now be considered in its regular working state, having a mass of heated fuel, mixed with partly fused and semi-reduced ore, called *browse*, floating upon a stratum of melted lead. The smelting shift is then regularly proceeded with by the two workmen, as follows:—The fire being made up, a stratum of ore is spread upon the horizontal surface of the browse, and the whole suffered to remain exposed to the blast for about five minutes. At the end of that time, one man plunges a poker into the fluid lead in the hearth-bottom below the browse, and raises the whole up at different places, so as to loosen and open the browse, and in doing so, to pull a part of it forwards upon the workstone, allowing the recently added ore to sink down into the body of the hearth. The poker is now exchanged for a shovel, with a head 6 inches square, with which the browse is examined upon the workstone, and any lumps that may have been too much fused, are broken to pieces; those which are so far agglutinated by the heat as to be quite hard, and further known by their brightness, are picked out, and thrown aside, to be afterwards smelted in the slag hearth. They are called "grey slags." A little slaked lime in powder is then spread upon the browse, which has been drawn forward upon the workstone, if it exhibit a pasty appearance; and a portion of coal is added to the hearth, if necessary, which the workman knows by experience. In the meantime, his fellow-workman, or shoulder-fellow, clears the opening through which the blast passes into the hearth, with a shovel, and places a peat immediately above it, which he holds in its proper situation, until it is fixed, by the return of all the browse from the workstone into the hearth. The fire is made up again into the shape before described; a stratum of fresh ore spread upon the peat; and the operation of stirring, breaking the lumps upon the workstone, and picking out the hard slags repeated, after the expiration of a few minutes, exactly in the same manner. At every stirring a fresh peat is put above the nozzle of the bellows, which divides the blast and causes it to be distributed all over the hearth; and as it burns away into light ashes, an opening is left for the blast to issue freely into the body of the browse. The soft and porous nature of dried peat renders it very suitable for this purpose; but in some instances, where a deficiency of peats has occurred, blocks of wood of the same size have been used with little disadvantage. As the smelting proceeds, the reduced lead, filtering down through all parts of the browse into the hearth-bottom, flows through the channel, out of which it is laded into the pig-moulds.

The principal particulars to be attended to in managing an ore-hearth properly during the smelting shift are these: First:—it is very important to employ a proper blast, which should be carefully regulated, so as to be neither too weak nor too powerful. Too weak a blast would not excite the requisite heat to reduce the ore, and one too powerful has the effect of fusing the contents of the hearth into slags. In this particular, no certain rules can be given; for the same blast is not suitable for every variety of ore. Soft, free-grained galena, of great specific gravity, being very fusible, and easily reduced, requires a moderate blast; while the harder and lighter varieties, many of which contain more or less iron, and are often found rich in silver, require a blast considerably stronger. In all cases, it is most essential that the blast should be no more than sufficient to reduce the ore, after every other necessary precaution is taken in working the hearth. Secondly:—The blast should be as much divided as possible, and made to pass through every part of the browse. Thirdly:—The hearth should be vigorously stirred at due intervals, and part of its contents exposed upon the workstone, when the partially fused lumps should be well broken to pieces, and those which are farther vitrified, so as to form slags, carefully picked out. This breaking to pieces, and exposure of the hottest part of the browse upon the workstone, has a most beneficial effect in promoting its reduction into lead; for the atmospheric air immediately acts upon it, and, in that heated state, the sulphur is readily consumed, or converted into sulphurous acid, leaving the lead in its metallic state; hence it is that the reduced lead always flows most abundantly out of the hearth immediately after the return of the browse which has been spread out and exposed to the atmosphere. Fourthly:—The quantity of lime used, should be no more than is just necessary to thicken the browse sufficiently, as it does not in the least contribute to reduce the ore by any chemical action; its use is merely to render the browse less pasty, if, from the heat being too great, or from the nature of the ore, it has a disposition to become very soft. Fifthly:—

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Coal should be also supplied judiciously, too much unnecessarily increasing th the browse and causing the hearth to get quite full.

When the ore is of a description to smelt readily, and the hearth is well ma every particular, it works with but a small quantity of browse, which feels d stirred, and is easily kept open and permeable to the blast. The reduction rapidly with a moderate degree of heat, and the slags produced are inconsidera if in this state, the stirring of the browse and exposure upon the workstone ar tinued, or practised at longer intervals, the hearth quickly gets too hot, mediately begins to agglutinate together, rendering evident the necessity operations to the successful management of the process. It is not difficult to un why these effects take place, when it is considered, that in smelting by mea ore-hearth, it is the oxygen of the blast and of the atmosphere which principall plishes the reduction; and the point to be chiefly attended to, consists in exp ore to its action, at the proper temperature, and under the most favourable stances. The importance of having the ore free from impurities is also eviden stony or earthy matter it contains impedes the smelting process, and incre quantity of slag. A very slight difference of composition of perfectly dressed be readily understood to affect its reducibility; and hence it is that ore from veins, or the same vein in different strata, as before observed, is frequently work very differently when smelted singly in the hearth. It happens, theref with the best workmen, some varieties of ore require more coal and lime, and degree of heat, than others; and it is for this reason, that the forestone is made so as either to answer for ore which works with a large or a small quantity of

It has been stated that the duration of a smelting shift is from 12 to 15 the end of which time, with every precaution, the hearth is apt to become too it is necessary to stop for some time, in order that it may cool. At mills w smelting shift is 12 hours, the hearths usually go on 12 hours, and are suspe four and a half or five bings* of ore (36 to 40 cwt.) are smelted during a shift, two men who manage the hearth, work each four shifts per week, terminati week's work at 3 o'clock on Wednesday afternoon. They are succeeded by t workmen, who also work four 12-hour shifts, the last of which they finish at on Saturday. In these 8 shifts, from 36 to 40 bings of ore are smelted, which, good quality, produce from 9 to 10 fodders of lead. At other mills, where th 14 or 15 hours, the furnace is kindled at 4 o'clock in the morning, and work 6 or 7 in the evening each day, six days in the week; during this shift, 5 or of ore are smelted, and two men at one hearth, in the early part of each we three such shifts, producing about 4 fodders of lead; two other men work each in the latter part of the week, making the total quantity smelted per week hearth from 30 to 33 bings.

Hearth-ends and Smelter's fume.—In the operation of smelting, as already d it happens that particles of unreduced and semi-reduced ore are continually expel the hearth, partly by the force of the blast, but principally by the decrepitatio ore on the application of heat. This ore is mixed with a portion of the fuel made use of in smelting, all of which are deposited upon the top of the smeltin and are called hearth-ends. It is customary to remove the hearth-ends from time and deposit them in a convenient place, until the end of the year, or som period, when they are washed to get rid of the earthy matter they may con the metallic portion is roasted at a strong heat, until it begins to soften an into lumps, and afterwards smelted in the ore-hearth, exactly in the same wa undergoing that operation for the first time, as already described.

It is difficult to state what quantity of hearth-ends are produced by the sm a given quantity of ore, but in one instance, the hearth-ends produced in smelt bings, on being roasted and reduced in the ore-hearth, yielded of common lead and the grey slags separated in this process gave, by treatment in the slag-h cwt. of slag lead, making the total quantity of lead 362 cwt., which is at the 3 cwt. 2 qrs. 23 lbs. from the smelting of 100 bings of ore.

The cost of smelting well-dressed galena at the ore-hearth is as follows:

			s.	d.
Labour			6	1·9
Coals 2·2 cwt.			0	4·4
Wood 1·2 „			0	9·1
Lime 0·6 „			0	3·5
Repairs			0	1·7
Engine Power:	Wages	0 10·7		
	Coals 5·2 cwt	0 10·4	=1	9·1
			9	5·7

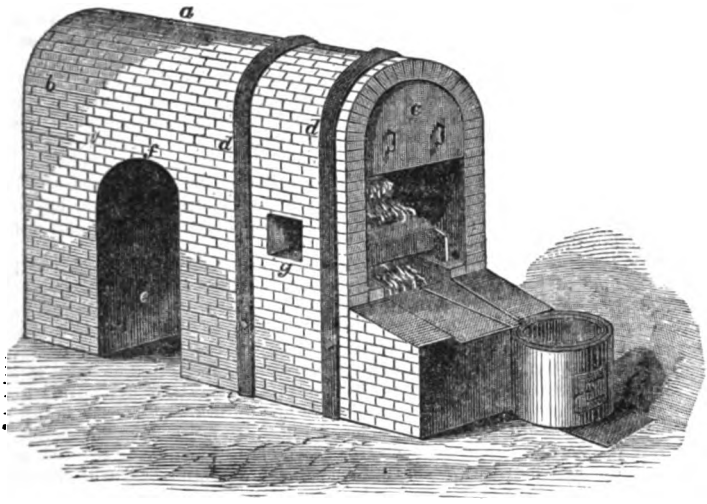
* 1 bing = 8 cwt.

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The ore-hearth, as usually constructed, often allows the fumes to fill the mill, whenever the draught is defective, and thus proves injurious to the health of the work people. Under all circumstances, a large volume of air passes into the flue, and so far diminishes the condensation of the lead-fume.

In order to diminish the objection, the writer introduced the following modifications, shown in *fig.* 610.

Fig. 610.



The hearth is covered with a hood of brick-work, *a*, at the back of which there is an opening into the flue. This opening can be enlarged or diminished by means of a damper, worked from the outside at *b*. The opening in front can also be regulated by means of a movable iron plate, *c*, which can be raised or lowered according to circumstances. The hood is firmly bound by iron straps, *d d*, which are maintained in position by screw-bolts above and below the hearth. The opening *e*, under the arch *f*, allows the workman to regulate the blast, which is admitted at the back through the ordinary tuyere.

The ore is charged through the opening *g*, in the side of the hood, and the furnace is worked from the front, in the manner just described.

We have now finished our account of the reduction of lead ores, and regret that we are compelled to omit many details relating to the various modifications adopted in Germany and elsewhere, which are treated at great length in Kerl's valuable *Handbuch der Metallurgischen Huttenkunde*, to which we beg to refer the reader for further information.

Chemical Reactions in the Blast Furnace.

The substances which compose the charge in blast furnaces, are generally either in the form of powder more or less fine, or in masses more or less fused.

The fume is in the form of powder, and consists chiefly of carbonate and sulphate of lead. The dross and lead skimmings are in coarse powder, and contain oxide of lead, and some metallic lead mixed with the ashes of the fuel and other earthy matters. The furnace-waste contains quartz, clay, and silicate of lead; while the test-bottoms consist either of silicates of lead, &c., or of phosphate of calcium and oxide of lead. The ores and the grey slags are very varied in their composition, containing sulphide and oxide of lead, sulphates and silicates of lead, calcium, barium, &c., and differ as much in their mechanical condition.

The chemical reactions resulting from the fusion of so varied a mixture of compounds, are necessarily of a very complex character, and change even in the different parts of the furnace; thus in the

Upper Zone.—The uncombined oxide of lead, which happens to be present in the furnace in the form of powder, or as a porous mass, is reduced, and as this lead trickles down to the hearth, a considerable portion is volatilised. It is necessary, therefore, in roasting ores, &c., to raise the temperature high enough to fuse them into masses, which are only acted upon, on the surface, by the reducing gases in the upper part of the furnace.

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The sulphide of lead is not easily decomposed by the aqueous vapour, and r
the lower zone almost unaffected. The sulphate of lead stands in the same relat
The compounds of iron, on the contrary, undergo a striking change, and in fac
the part of reactives in the lower zone, in consequence of their reduction in this
the furnace. A high furnace is necessary to complete this reduction, but such a f
would be unsuitable for lead for the reasons previously given. The size of the
of these iron compounds, must therefore be regulated by the height of the furnace,
smaller as the furnace is lower.

Lower Zone.—The matters thus prepared in the upper zone, soften, and gra
enter into fusion as they descend, undergoing very complicated chemical changes
are difficult to regulate, and in which the reducing gases exercise little actio
where the solid fuel comes into operation.

The favourable working of the furnace is also assisted, inasmuch as the materi
not all equally fusible, and do not all soften at the same time. The matters cont
the oxide of lead and the slags, melting first, gradually absorb the gangues and p
silicates rich in lead. The sulphates are rapidly decomposed by the melted sil
and they produce very little sulphides under the reducing action of the solid fuel
sulphide of lead present, mixes with the metallic silicates, the reduction of the
compounds commencing only after the formation of the silicates. The reducing
is due chiefly to the metallic iron and solid fuel, the sulphides of barium and c
also assisting in the production of the metallic lead.

Action of the Iron.—This metal decomposes part of the oxide and sulphide o
forming sulphide of iron and oxide of iron, which combines with the silicates.
sulphide of iron acts energetically on the silicate of lead, producing sulphurou
protoxide of iron, and metallic lead. When the roasting has been complete, t
little or no matt formed, and when a sufficient supply of iron has been produ
the upper zone, the lead is all precipitated and the slags then contain no oxide o

The solid fuel assists the action of the iron, but its contact is of course muc
intimate than that of the metal, which ought therefore to be always present in th
portion of an equivalent for every equivalent of lead. Under such circumstanc
slag is very fusible, and does not contain particles of lead, which being reduced
lower zone the loss by volatilisation is as small as the volatile nature of this
permits.

The important point consists in the reduction of sufficient iron in the upper
without necessitating the employment of a very high furnace. In a *lit de fusio*
taining 40 per cent. of lead, there ought to be 9 per cent. of iron in the metallic
or an equivalent quantity of iron ore.

Iron borings, cast iron, &c. have been used, but the proportion of this metal
still be in equivalent quantities to the lead, and they do not act so well as iron
divided, produced by the reduction of the iron ores.

Action of the Coke.—The reducing action of the solid fuel may be made to ta
place of the iron, but unless the gangues and other substances contain sufficient
of iron to produce a fusible slag, the latter will consist only of earthy bases, req
a high temperature for fusion, and thus increasing the loss of lead by volatilisa

Coke has no action on the sulphide of lead, and as the fuel is charged in large
its reducing action is limited to surface contact. The fuel should therefore be re
to powder, and intimately mixed with the *lit de fusion*, while the roasting of the
compounds should be as complete as possible. This latter operation would, ho
require a long time, and its expense would prove a great objection. We made
experiments on this subject, and found that it required upwards of thirty
roasting to bring the sulphur, in pure galena, down to 4½ per cent.

The employment of the fuel in powder, is also attended with the inconvenienc
great heat at the furnace-mouth, and the reduction takes place high above the t
which causes a great loss of lead and silver by volatilisation. It is necessary
fore to employ very low furnaces, and to conduct the fusion very slowly; but w
the aid of the iron there is always an increased loss of lead, when the reduction de
upon the fuel, and with such furnaces, the iron-compounds act simply as fluxes.
the contrary, in a furnace of suitable height, the intimate mixture of the iron or
the fuel, is very effective, the whole of the metal acting as a reducing agent.

The reducing action of the fuel is attended with another difficulty, as it facil
the conversion of the sulphates into sulphides, which then go to form more o
matt. In the case of the sulphates of baryta and lime, the reducing action
fuel is however, to some extent, beneficial, as these substances assist in decomposi
oxide of lead.

When the matts are poor in lead and silver and not in large quantity, their pr
is not very objectionable. We have often worked a furnace where the matt cont
only 1·1 per cent. of lead, and 10 dwt. 10 grs. silver per ton. They indicate, whe

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either imperfect roasting in the lead-compounds, or a deficiency of the reducing agents, sulphides of iron, barium, or calcium.

Iron Pyrites as Reducing Agent.—This mineral should be previously roasted to expel a portion of the sulphur, when it is to be used in the blast-furnace, but its employment has a tendency to increase the formation of matt. The same effect is produced to a greater extent, when the galena employed is loaded with pyrites, since these two sulphides enter into combination in the upper zone of the furnace, and the matt produced does not act so vigorously upon the silicates as the sulphide of iron alone. The matt therefore partly escapes decomposition, and the quantity is accordingly increased.

Fume.—This substance, being in the form of powder, ought not to be charged direct, but it should undergo a preliminary treatment in a reverberatory furnace. It is advisable to mix it with some lead-compounds and a quantity of sand, varying from 15 to 20 per cent., according to its contents in lead. The charge is rapidly heated to the point of fusion, and about 8 per cent. of fuel, in small pieces, added. The whole is then well worked, to mix the fuel as intimately as possible, which promotes the separation of the lead obtained by the reduction of the silicate of lead.

Action of the Gangues. *Carbonate of iron.*—This substance is converted, more or less, into sesquioxide of iron during the roasting process, and only interferes with the oxidation of the galena when present in large quantities. It acts in the furnace in the manner already explained, and must be regarded as a useful impurity; but when present in larger quantities and intimately mixed with the lead ores, it prevents the agglomeration of the powder, even when sand is added. Under such circumstances, the reducing action must be moderated in the upper zone of the furnace, and the union of the oxides of iron and lead with some fusible siliceous slags, must be promoted. The furnace ought to be low, and driven with a gentle blast; but with all precautions, there is a tendency to *gob* the furnace.

Iron pyrites.—When this mineral is present, the roasting requires a longer time, and it is difficult to prevent the agglomeration of the ores, with an undue formation of sulphates. Towards the end, the heat must be raised, and the presence of an excess of sand is necessary. The loss of lead and silver by volatilisation in such ores is less, however, probably, from the rapid formation of sulphuric acid by the oxidation of the pyrites, and the conversion of the lead and silver into sulphates.

When the roasting is complete, the only reducing agent necessary in the blast-furnace is coke, the action of which has been previously explained.

The arsenical pyrites is always injurious; the formation of arsenious acid during the roasting, increases the volatilisation of the silver, but the greater part of the arsenic remains behind in the form of arsenates. In the blast-furnace, some more arsenic is volatilised in the upper zone, and part remains combined with the lead and in the matt in the form of arsenuret of iron.

Sulphide of antimony.—During the roasting, the volatility of the antimony increases the loss of lead and silver, and towards the end of this operation, it is impossible to decompose the antimonates, even with an excess of gangues and fusible silicates.

In the blast-furnace, the antimonates are gradually reduced by the gases, the iron, and the solid fuel, with the same facility as the compounds of lead. A part of the antimony is volatilised, by which the loss of lead and silver is increased, and another portion passes into the lead and matt. The presence of this substance necessitates the use of an increased proportion of iron and coke. The antimony also accompanies the lead in all the subsequent operations, although the greater portion can be removed in the calcining process.

Copper pyrites.—In the blast-furnace, the copper is nearly all reduced at the same time as the lead, and when a matt is formed, a portion of the copper is always present. The lead, however, always carries away some copper, which reappears in all the subsequent operations, after giving a characteristic appearance both to lead and litharge.

Blende.—During the roasting, the blende is more rapidly oxidised than the galena, being converted into oxide and sulphate of zinc, which is decomposed with difficulty in the second period, while the infusibility of the oxide impedes the melting of the other materials. It is, therefore, necessary to add some argillaceous compounds to such galenas, and prolong the roasting process. These compounds of zinc are not volatile, but, being infusible, are more liable to be carried off with the current of fume, of which they always form a large proportion; these fumes are richer in silver than those formed in treating similar galenas free from blende. It is not known in what state of chemical combination the silver exists in fume, but from the facts observed in treating ores with different gangues, it would appear that the presence of silver in the fumes is due more to mechanical than to chemical causes.

In the upper zone of the blast-furnace, the oxide of zinc is partially reduced, and as

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the metal descends, it is volatilised, when it acquires a dark red heat, and burns at t mouth of the furnace, spreading its oxide on all sides. This metal has therefore beneficial action on the reduction of the lead.

In the lower zone, the oxide of zinc combines with the silica and retards the fusi while the iron does not easily reduce it, and the metal, once formed, is volatilis without any appreciable action on the silicates with which it comes in contact.

The slags contain some oxide of zinc, which render them of a refractory charact The lead produced, does not contain much zinc, as the temperature is too high to fav the combination of the two metals.

When the roasting has been imperfect, the sulphide of zinc is partially oxidised the aqueous vapour in the upper zone of the furnace, but the greater portion unites w the sulphide of lead, and forms matt. The greater porosity of these roasted materi from the presence of the infusible zinc-compounds, increases the reducing action of gases in the upper zone, and this again adds to the quantity of matt which is form This zinc-matt is, however, not so fusible as the others, and consequently rema longer in contact with the silicate of lead, on which it exerts a reducing action, only benefit derived from the presence of blende.

The volatility of the zinc increases the loss of lead and silver in various ways, by direct action, as well as by its rendering the roasted materials more porous, in con quence of the infusibility of its compounds in all the operations of roasting, smelti and treatment of the fume.

The great object therefore in treating such ores is to diminish the chances of vol lisation, by perfect roasting, and the addition of fusible slags in sufficient quantity overcome the infusibility of the zinc compounds. The beneficial action of iron pyri in such ores, is due to the facility with which it melts, thus counteracting the oppos tendency of the blende; but the quantity necessary to accomplish this effect may the percentage of blende is great, prove so large as to render the ore too poor for a kind of metallurgical treatment.

II. The Refining of the Lead.

All lead ores contain more or less silver, and as the latter metal is reduced alo with the lead, its separation becomes an object of commercial importance. The cost separating silver by the old plan of cupellation, renders it impossible to refine le with less than eight ounces of silver per ton, and the world is indebted to the late M Pattinson for the discovery of a beautiful process, by which lead with no more th ½ oz. will now pay for its extraction.

The separation of silver, therefore, now involves three operations, viz. desilveri tion, cupellation, and the reduction of the pot-dross and litharge.

1. Desilverisation.—Pattinson's *Process.*

This process, known among the workmen as the *separating* process, and called France, *Pattinsonage*, consists in slowly cooling the melted lead in iron pots, duri which a portion of the contents assume a crystalline form, and sink to the botto These crystals contain less silver than the portion which remains in a liquid state.

The composition of this desilverised lead, from different localities, is given in t table below.

Analyses of Desilverised Lead.

Locality .	Altenau.	Stolberg.	Billach.	Eschweiler.	Pirach and Jung.	English
Analyst .	Streng.	Streng.	Streng.	Streng.	Streng.	Streng.
Lead . . .	99·957	99·935	99·975	99·907	99·892	99·980
Antimony . .	0·021	0·007	0·012	0·053	0·061	0·015
Copper . .	0·016	0·050	0·007	0·026	0·041	trace
Iron . . .	0·006	0·006	0·006	0·003	0·004	0·008
Zinc . . .	trace	0·001	trace	0·011	0·002	0·004
	100·000	99·999	100·000	100·000	100·000	100·010

The pots are large metal pans, and are generally set in a row of 10 or more, those the left being called the *working* pots, and that to the right, which is smalle the *market* pot, from the circumstance, that the *poor* lead is ladled from it into t pig moulds, ready for market.

The mode of setting a range of these pots is so clearly shown in *fig.* 611, as supersede the necessity of any description.

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Fig. 611.

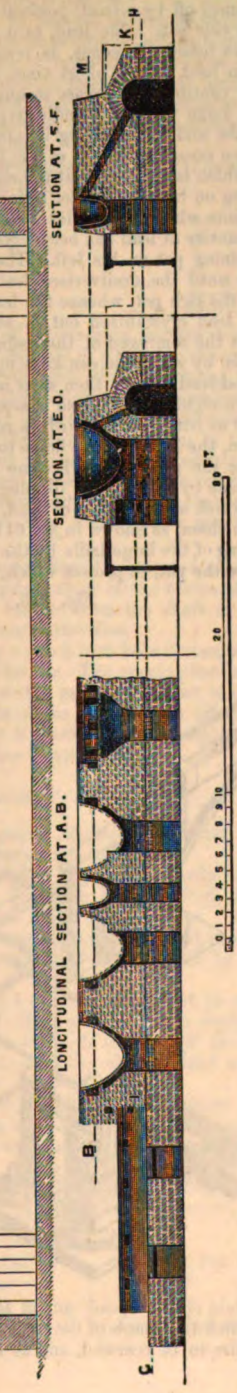


Fig. 612.



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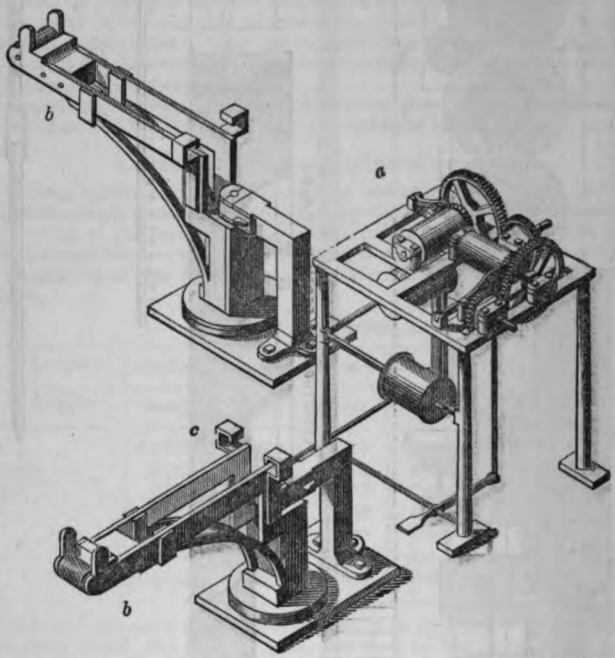
The operation is conducted in the following manner:—One of the pots about middle of the range is filled with pigs of lead, which are melted. The dross which fo on the surface is skimmed off by a small perforated ladle, when the fire is withdr from the grates below this pot. The lead, as it cools, is constantly stirred, and portion which solidifies round the edges, is removed by an iron paddle or *slice*, mixed with the molten lead. In a short time, the crystals, above mentioned, m their appearance, and continue to increase in quantity as the cooling progresses. workman then dips a large perforated ladle, represented in *fig.* 612, into the mas liquid lead and crystals, and withdrawing it, allows the liquid portion to drain aw which he hastens by an occasional shake of the ladle. He then attaches to the sh of the ladle, a hook, which is suspended at the end of a chain hanging upon the jo of the roof, and holding on by the handle, swings the ladle full of crystals over next pot to his right, into which he empties the crystals. He continues this operat until the necessary quantity of lead has been crystallised out, when the liquid port is ladled into the adjoining pot on his left. The same operation is repeated with the intermediate pots, until the desilverised lead arrives at the market-pot, and enriched lead reaches the rich pot, whence the lead is taken for cupellation.

The proportion of lead crystallised out in each pot varies very much with richness of the lead at the command of the refiner, and especially if he has *origi* leads of different values, by which he can keep up a continuous supply of lead to e pot. When the original lead is poor, then what is known as the *low system*, is adopt where as much as seven-eighths of the lead is separated; but with richer lead, the *h system* is followed, and as little as two-thirds is removed as crystallised lead.

During the operation, the large ladle is liable to cool by its repeated exposure to air, and in consequence the perforations become closed by the adhesion of the le This difficulty is overcome by occasionally dipping the ladle into the small intermedi pots on the one side, which are kept full of lead, maintained at a higher temperat by a small fire beneath them, as shown in *fig.* 611.

The shaking or jerking of the large ladle by the workmen when draining the cryst would ultimately injure the pot, to protect which, a pig of lead with a bar of iron c

Fig. 613.



in its upper surface, is laid on the broad rim of the pot, and this serves at the sa time as a fulcrum on which the shank of the ladle rests.

These pots often require to be renewed, and as a large weight of metal in the ri

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is rendered useless in each renewal, the upper portion of the brickwork is covered in some works with a circular metal slab, on which the narrow rim of the pot rests, by which a saving of expense in the repairs is effected.

This process is also accompanied by another advantage in purifying the lead. Each time the lead is melted, the surface becomes covered with a scum, which contains more or less impurity along with the oxide of lead, and this dross being always skimmed off, the quality of the lead is continuously improved as it approaches the market-pot. This circumstance is so well recognised, that leads containing only one ounce silver per ton, and even less, are regularly treated by this process, especially when the lead is to be used in the manufacture of white lead.

An average cost, founded on the crystallisation of 1,917 tons of lead containing 24 ounces of silver per ton, was found to be as follows:

	s.	*d*
Labour	9	7·6
Coals, 6·2 cwt.	1	0·4
Repairs	0	2·9
	10	10·9

Stagg's apparatus.—The expense of labour is an important item in Pattinson's process, and none but powerful men are capable of managing the crystallising ladle. This objection attracted the attention of the late Mr. I. D. Stagg, who succeeded in constructing an apparatus for obviating this difficulty. This arrangement, known as *Stagg's apparatus*, is represented in *fig.* 613; it consists of a crane and windlass, *a b*; a chain attached to the end of the shank of the ladle is wound up by the windlass, and draws up the ladle, filled with crystals, out of the pot. A workman guides the handle of the ladle, which is afterwards placed under a catch, *c*, of the crane. While the crystals are draining, the ladle is occasionally shaken by the workmen, and by moving the crane, the ladle is easily carried over the adjoining pot, into which the crystals are emptied.

Worsley's apparatus.—This gentleman has also patented arrangements by which the labour is economised. He fixes an upright shaft in the centre of the pans, with a bearing at top and bottom, while arms radiate from the shaft to the sides of the pans; with this apparatus he obviates the use of the slice.

The other plan consists in drilling a ¼ to ½ inch hole horizontally through the side of the pan, about two inches above the bottom. The opening inside the pan is covered with a sheet-iron strainer screwed down to the pan, and a spout is set in an opening made through the side wall of the fire-hole of the pan, to carry off the liquid lead into a pot placed outside. The hole in the pan is made tight by a slightly tapering *tapping bar*. The crystals remain behind for further treatment.

Parkes' *Process.*

This process depends upon the superior attraction of silver for zinc over lead, and is applied by Mr. Parkes in the following manner:

The silver-lead is melted in one of the large pans already described, and raised to the temperature of melted zinc. The zinc being melted, is then added, and the fluid metals are stirred for a period of one to two hours. The fire is now lowered and the metals allowed to cool down until the lead is about to set. The zinc and silver rise to the surface during the interval, and are removed by means of a perforated ladle.

This alloy is afterwards heated in a sloping iron retort to remove a portion of the lead, which contains 1,000 ounces of silver per ton, and is ready for cupellation. The portion left in the retort, is heated in clay pots to distil off the zinc. The residue contains silver mixed with the impurities of the original lead and zinc. It is melted with lead and cupelled to obtain the silver.

Mr. Parkes also proposed to roast the alloy in close retorts or muffles, by which it was reduced to a fine powder, which was then to be treated with dilute sulphuric acid. The foreign oxides dissolved in the acid, leaving the silver, which was treated in the usual way.

The quantity of zinc required to desilverise the lead, depended upon the proportion of silver and other metals present in the lead, and he gave the following statement in his specification—viz. for 20 cwt. of lead containing

14 oz. of silver per ton . . .	22·4 lbs. of zinc.
21 „ „ „ . . .	33·6 „
28 „ „ „ . . .	44·8 „

The loss of lead in this process is said to be about 1 per cent., but on account of

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the difficulty in treating the alloy of zinc and silver, Messrs. Neville are understood have abandoned the plan.

Separation of Copper in Crystallisation.

Mr. Baker has published the following results of an inquiry to ascertain how far t impurities of lead, viz. silver, copper and iron, are removed in this process of crystal sation.

The original lead contained:

	1	2
Silver . . .	0·0046	0·0052
Copper . . .	0·0066	0·0154
Iron . . .	0·0065	0·0068
Sulphur . . .	trace	trace.

The various products of the process contained:

	Silver.	Copper.	Iron.
Rich Pot:—			
Before crystallising . . .	0·0108	0·0344	0·0312
Crystals, 25 pts. . . .	0·0052	0·0152	0·0086
Fluid lead, 85 pts. . . .	0·0140	0·0476	0·0122
Second Pot:—			
Before crystallising . . .	0·0052	0·0154	0·0068
Crystals, 95 pts. . . .	0·0020	0·0066	0·0118
Fluid lead, 25 pts. . . .	0·0126	0·0286	0·0146
Third Pot:—			
Before crystallising . . .	0·0020	0·0102	0·0118
Crystals, 70 pts. . . .	0·0010	0·0038	0·0198
Fluid lead, 25 pts. . . .	0·0100	0·0240	0·0082
Fourth Pot:—			
Refined lead	0·0014	0·0054	0·0112

From this Mr. Baker very naturally draws the conclusion that there is an alloy copper-lead which remains fluid when crystals of lead are formed, and that when t former metal is present in moderate proportions, it may be separated from the lat by a process similar to that of Pattinson.

This statement has been disputed by Reich and Streng, who deduce from their e periments the conclusion, that the copper is not separated; but the writer, witho having analysed the different leads, inclines to believe in the correctness of Mr. Bake conclusions.

2. Cupellation or Refining of the Rich Lead.

Although it may be difficult to assign a correct interpretation to Hebrew terms art, yet we think it is clear that the use of lead in purifying other metals was kno in very ancient times. Jeremiah would seem to allude to this fact in the passage ch. vi. ver. 29, and similar reference is made in Ezekiel xxii. 18–22, Malachi iii. 2, The first notice of the process of cupellation among the ancients, appears in t works of Dioscorides; and Pliny and Geber describe an operation which is a tr cupellation by means of lead. In 1343, Philippe le Bel issued an ordinance prescri ing the use of cupels for testing the precious metals. In 1556, Agricola in his wor *De re Metallica*, fully describes the whole process, with instructions how to make t tests; this was followed by the work of Barba, *Arte de los Metales*, in 1640, where t construction of the refining furnaces is minutely explained.

The chief object is generally to separate the silver from the lead, but when an oxi of lead in the form of litharge is wanted, then the former becomes a secondary operatio

There are many modifications as to the form of furnace, mode of refining, &c., b only what may be called two distinct methods of cupellation—viz. the English a German.

The English System.

The peculiarities of this system consist in the cupel being movable, and the lea being fed at intervals.

The furnace, which is termed a *Refinery*, is represented in *figs.* 614, 615, where tw cupels can be worked at the same time when necessary; *a a* are the positions of th cupels or tests, one of which is shown resting on an iron waggon, *b*; *c c*, the pots contai ing the rich lead in a melted state, which is ladled into an iron gutter, *d d*, to suppl the test; *e e*, the point where the blast enters, and *f f* the opening or *gate*, through whic the litharge is blown over into a pot below; *g g*, the fire grates, and *h h* the ash pits *i i*, the flues, and *k k* the chimneys.

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Fig. 614.

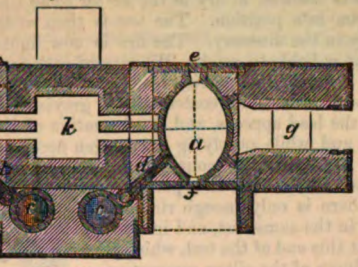
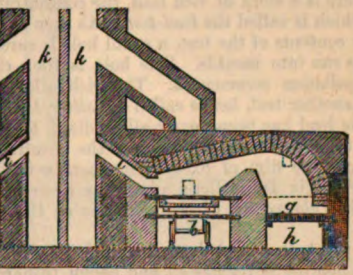


Fig. 615.



eratory furnace is formed of bone-ash, finely ground, with a very weak solution of pearl-ashes. This

Fig. 616.

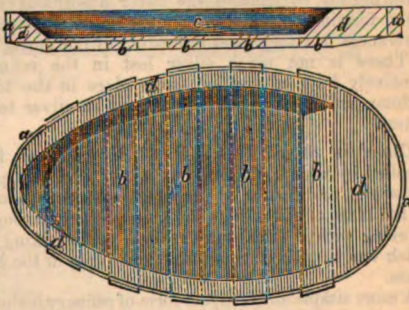
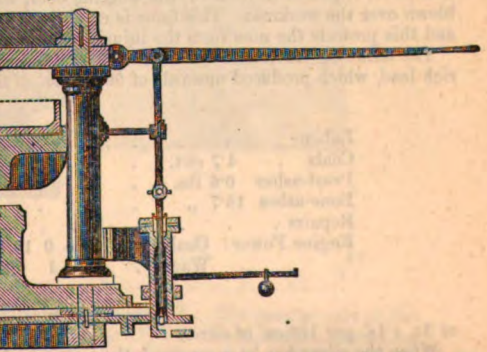


Fig. 617.



s apparatus is shown in *fig.* 617 in such detail as to . It is worked by hydraulic pressure.

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The test is allowed to dry in the air for some time, and then placed on the waggon, which is run into position. The test is then wedged tight up against an iron ring built firmly in the masonry. The fire is now lighted and the test carefully annealed, otherwise it is liable to crack. When perfectly dry, it is heated to a dull redness, and then filled with the melted rich lead.

This lead soon becomes coated with a greyish dross, but as the heat increases, the surface of the lead appears, and the formation of litharge commences. The blast is now turned on, and while supplying the oxygen necessary for the oxidation of the lead, it drives the litharge to the mouth of the refinery, where it flows in a continuous stream over the gate into a little iron pot placed on wheels for the convenience of removal.

When there is only enough rich lead to yield a small cake of silver, the refining is completed in the same test, and in that case, the workman cuts down the opening in the bone-ash at this end of the test, which is called the gate, to the level of the melted lead, until the *fining* of the silver commences.

When there is a stock of rich lead, the concentration of the silver is confined to the first test, which is called the *lead-test*. As soon as the silver amounts to about 8 per cent. of the contents of the test, a small hole is carefully drilled in the bottom, and the rich alloy is run into moulds. The hole is then closed by a pellet of bone-ash, and another cupellation commenced. The rich alloy is afterwards refined in the same manner in another test, hence called the *silver-test*.

When the lead has been nearly all oxidised, the film of silver becomes thinner and thinner; it then exhibits a succession of the beautiful iridescent tints of Newton's rings, and at length the film of oxide disappears, revealing the brilliant surface of silver beneath. Such is Dr. Miller's admirable description of this beautiful phenomenon, known as the *fulguration* of the metal, or as the men call it, the *brightening of the plate*.

At this point the blast is turned off, the fire withdrawn, and the silver allowed to cool. When the silver has *set* and begun to harden, the wedges are removed, and the test with its cake of silver falls on the iron waggon. When cold, it is removed, the impurities adhering to its under surface are chipped off, and the silver is ready for fusing into ingots.

During the cupellation, the silver absorbs oxygen, which is evolved as the metal cools, forming crater-like eruptions on the surface, and the extent of these protuberances is a very good indication of the purity of the silver.

There is not much silver lost in the refinery by volatilisation, but a comparatively large absorption takes place in the test. We have assayed several test-bottoms, and have found the contents in silver to vary from 74 oz. to 115 oz. per ton of test.

Chambers' Steam Blast.—The blast employed in refining must be soft, and is best supplied by means of a fan, but a very excellent plan of Mr. Chambers was tried by the writer, and furnished very good results. It consisted in substituting a steam jet for the blast of air, and as the steam passed through a wide nozzle, it carried sufficient air along with it to oxidise the lead, while mixing a body of steam with the lead fume, which was thus more completely recovered in the long flues by the condensation of the steam.

A more simple and compact form of refinery is shown in *figs.* 618, 619, where the steam blast-pipe is represented entering the furnace at *a*. This refinery is also fitted with an iron hood, *b*, placed in front of the working door, where occasional puffs of fume are blown over the workman. This fume is carried off by an iron pipe, *c*, into the chimney, and this protects the men from the injurious consequences of inhaling the lead smoke.

The following statement as to the cost of refining, is founded on the cupellation of rich lead, which produced upwards of 60,000 oz. of fine silver:

							s.	d.
Labour							3	10·3
Coals	4·7 cwt.						0	9·4
Pearl-ashes	0·6 lbs.						0	4·0
Bone-ashes	18·7 „						3	3·8
Repairs							0	2·0
Engine Power:	Coals cwt.	5·2	=	0	10·4			
	Wages			1	0·3		= 1	10·7
						Per ton of lead	10	4·2

or 3*s.* 1·1*d.* per 100 oz. of silver.

When the silver has been removed, the test is broken up, those portions of the bone-ash which are free from lead, being removed for subsequent use, and the rest is generally

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carried to the slag-hearth or blast-furnace, where the bone-ash of course is lost. Mr. Johnson recovers this bone-ash as follows:—

Johnson's Process.—He reduces the cupel to a powder, and mixes it with acetic acid of 1·030 to 1·048 specific gravity, in sufficient quantity to render the mixture of a thin

Fig. 618.

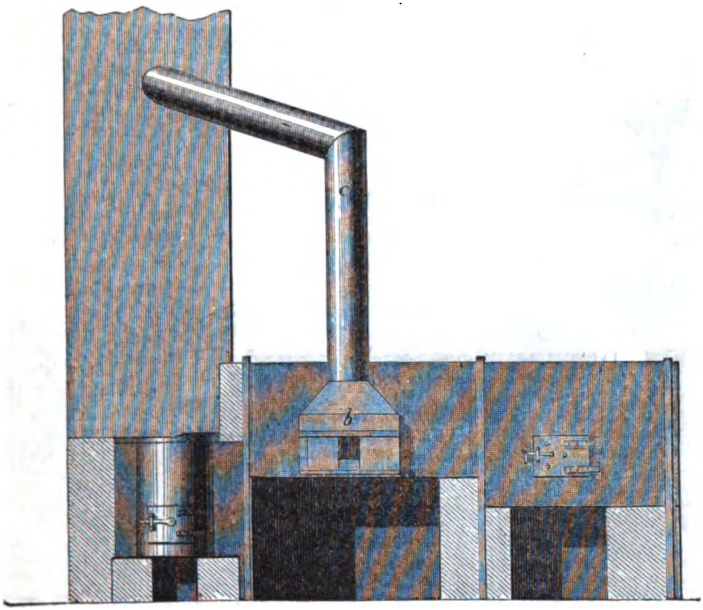
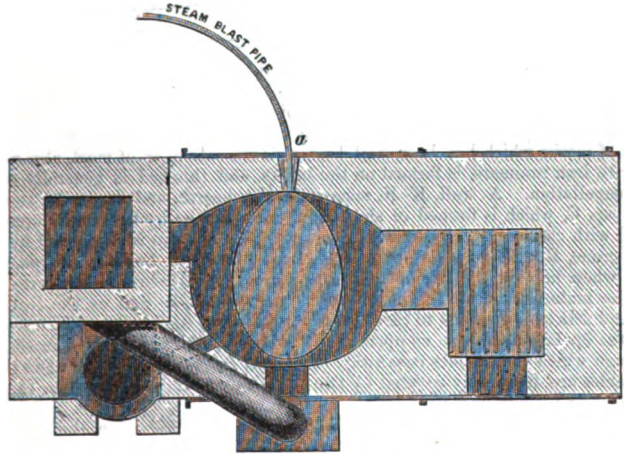
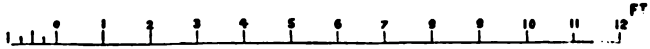


Fig. 619.





consistence to admit of its being well agitated in a dolly tub. The greater part of the lead dissolves, and by renewing the acid, a further quantity is removed, so that, on working the residue to separate all the solution, the bone-ash is sufficiently pure to be employed again in making tests. The solutions yield the lead, in the form of sugar of lead, by concentration.

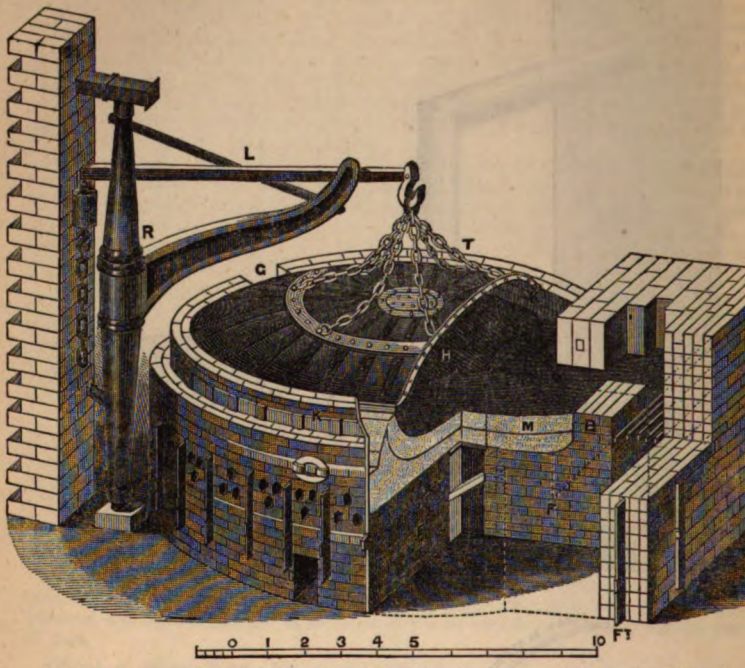
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The German System

differs from the English in forming the hearth of marl instead of bone-ash, making it of large dimensions, and charging all the lead at one time.

The form and construction of this furnace is shown in *fig.* 620, which is tak an excellent treatise on the Metallurgy of Lead by Dr. Lamborn. The corne

Fig. 620.



right is removed, to show the interior. The circular portion contains the heart rectangular fireplace. The foundations, F F, are built of stone, cramped with ir and pierced with openings to carry off the moisture. A, represents the firep which either wood or coal can be burnt. The hearth is formed of bricks set on a bed of scoriæ which has been well beaten down. A layer of marl, also c beaten with iron rammers, is formed on the bricks, and this bed is generally r at each cupellation. A wall, K K, surrounds the hearth, and serves to su movable cap, C, which is formed of sheet iron, strengthened by bars on its upp and lined with clay secured by numerous iron straps. The cap is suspended by from the crane, R, and supported by a lever, L, so that it can be raised or rem one side, when necessary. The opening, G, opposite the fire-bridge, B, serves troduce the materials of which the hearth is constructed, as well as the lea refined, and acts as a chimney to carry off the products of combustion. The w watches the operation through an opening in the corner, which is removed in th cut, through which the vapours pass away. The blast enters at T, through two t whose nozzles are frequently covered by two small valves, called *butterflies*, to the blast over all the surface of the bath.

When all is ready for work, a thin bed of straw is laid upon the hea which the pigs of rich lead are piled. The cap, C, is then lowered on the walls, an with clay all round the edges. The fire is then lighted, and soon after the melted, its surface is covered with a dark crust called *abzugs*, consisting of the ox the foreign metals, and other impurities from the lead. This crust is drawn off t the working door, opposite T. The fire is kept up to maintain the lead at a da heat, while the impurities, termed *abstrichs*, continue to separate. The table follows, contains the analysis of some of these products. The next product appears, is known under the name of *cupreous* or *wild Litharge*, and at the end hours, the formation of the true litharge commences. The heat is now mai between a cherry and a bright red, until the operation is complete.

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the Products of Cupellation.

Abstrichs.						*Abzugs.*	
Holzapfel, 2nd.	Villefort.	Freiberg.	Katzenthal, 1st.	Katzenthal, last.	Pontgibaud.	Poullaouen.	Pontgibaud.
68·00	82·00	95·50	67·60	88·80	89·50	35·10	53·1
trace	. .	0·50	0·40	. .	0·20	4 60	1·1
. .	. .	1·10	0·20	. .	1·50	5·00	4·6
4·00	. .	0·30	4·40	. .	2·60	5·10	5·4
with Sil.			with Sil.	with Sil.		0·80	
acid	. .	. .	acid	acid	. .	0·70	
14·00	. .	. .	7·60	5·00	. .		
14·00	17·60						
. .	. .	. .	. .	. .	. .	4·80	0·5
. .	. .	2·30	19·70	6·20	0·70	. .	3·0
. .	. .	. .	. .	. .	. .	5·80	
. .	0·40	. .	0·30	. .	. .	6 80	C, 5·6
. .	. .	. .	. .	. .	. .	3·40	23·0

arge obtained, distinguished by their colour, *yellow* pieces, while the latter is in flakes. The difference ion, which results from a difference in the cooling.

nalyses of Litharge.

	Halsbrücke.		Clausthal.	Unter-Harz, last.
	red.	black.		
Plattner.	Rammelsberg.		Brüel.	Ulrich.
. .	96·35	94·68	99·69	58·13
0·95	1·35	0·59	0·40	0·28
. .	0·66	0·59	trace	35·25
. .	. .	. .	. .	0·71
1·56				
. .	0·45	0·59	. .	3·75
. .	2·70	2·00		
. .	0·49			

approaches a termination is marked by the brighten- e hot water is thrown over its surface, and as soon as vater is used to harden the cake. This silver contains ined by another process.

ion of Lead from Bismuth.

been employed by Patera to separate the two metals, hal in Bohemia, the small quantity of bismuth in the rich lead, and when the latter is submitted to cupel- appearance towards the end of the operation. This ," is reduced and refined in the usual way. The lead ismuth, nearly pure, on the test. This impure metal and the bismuth so obtained is very pure, as indicated

smuth .	99·58
lver .	0·42
ad . .	trace
on . .	trace
	100·00

reducing the black litharge, consists of:

ismuth .	34·5
ead . .	65·5
	100·0

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The progress of the cupellation is carefully watched, and samples of bot litharge and the metal on the test are analysed from time to time. The mixed are dissolved in nitric acid, and an excess of hydrochloric acid is added to conve metals into chlorides. Strong alcohol is added, which precipitates the chlori silver and lead, and the bismuth is thrown down from the solution by carbon ammonia, then filtered, and weighed.

Manufacture of Litharge.

An oxide of lead is in demand for the preparation of acetate of lead and purposes, and this substance is produced in two forms, as *Flake* and *Lev* litharge.

Flake Litharge.—When litharge is manufactured for sale, the purest lead, n in silver, is selected for cupellation. The refining process is conducted as a described, but the oxide of lead at the commencement and termination of the cu tion is rejected.

The litharge, as it flows from the test, is received in large pots fitted on whe which it is allowed slowly to cool. In some cases, the pots are heated so th cooling may be more gradual, as the proportion of the flake litharge depends upo condition. When the pots are emptied, the mass of litharge falls, and the wh passed through a circular temse, working in a close wooden erection to protect th from the dust. The fine flake litharge is collected and packed in casks.

Levigated Litharge.—The portion of litharge which does not fall, but remains i fused pieces, is employed for the manufacture of levigated litharge.

The process consists in simply grinding this fused litharge between horizontal with a supply of water. The mill employed for the purpose is seen in *figs.* 621

Fig. 621.

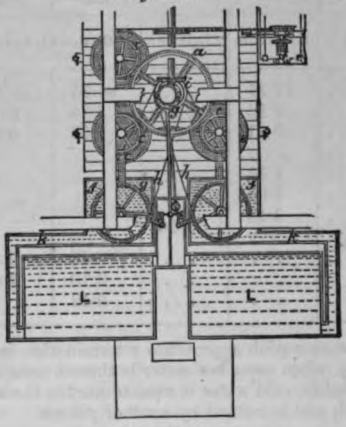
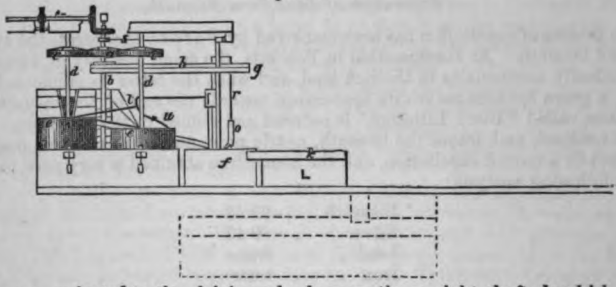


Fig. 622.



Motion is communicated to the driving wheel, *a*, on the upright shaft, *b*, which into the wheels, *c c c*, on the spindle *d d d*, turning the upper stones of the pairs *e e e*. The litharge, along with a small stream of water, is fed into the pairs, as it is seldom necessary to pass it through two sets of stones. The g mass then falls into the dolly-tubs, *f f*, which are agitated by means of the sh *g g* driven by the belts, *h h*, working round a sheave, *i*, on the upright shaft. Th

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ater along the spouts, *k k k k*, and deposits in the
ll of water. The overflow escapes at *m*, into the
ee pumps, *o o* and *p*, all worked by gearing, *r*, *s*, in
he water from the pumps, *o o*, supplies the dolly-
romoting the separation of that portion which is
ted in the broad spouts, *k k k*. The pump, *p*,
itharge as it enters the eye of the stones, through
utside cases and rims of the stones, through the

itharge, they are allowed to stand for some time.
is run off by plugs or siphons. The litharge is
w heat in a reverberatory furnace. It is afterwards

THE POT-DROSS AND LITHARGE.

r less of the lead is converted into an oxide, in the
ns, and as litharge in the cupellation.
ances are reduced resembles the smelting furnace,
character. The sole slopes from the fire-bridge to
gutter is inserted in the brickwork, which is never
uns into an iron pot on the outside, whence it is

nd plan in *figs.* 623, 624, where **A** represents the

Fig. 623.

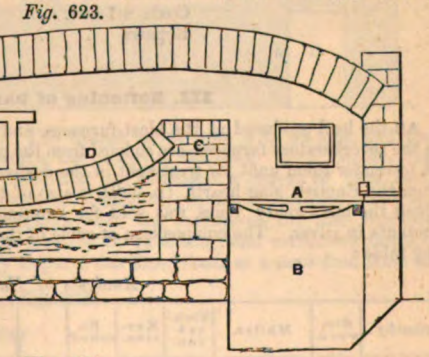
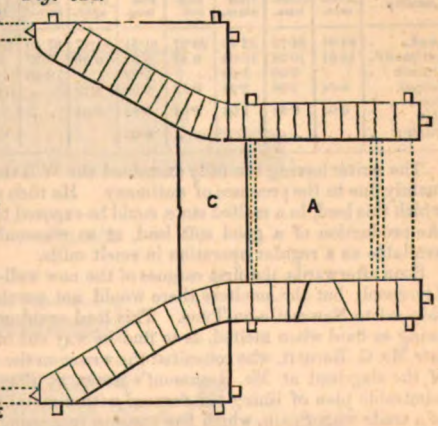


Fig. 624.



; D, hearth; E, working door; F, the iron spout;
fire below.
quantity of coal, on which a mixture of the oxides

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and coal is thrown near to the fire-bridge. The ignition of the fuel and the reduc gases in the furnace soon causes a reduction of the metallic oxides, and the liq metal trickling down through the porous mass, finds its way to the point, F, whenc flows into the metal pot, G. The charge is frequently turned over by an iron rak present fresh surface to the reducing action of the fuel, and to facilitate the escap the lead. Fresh charges are introduced during the shift, and at the close of the the residual matters, termed *cinders*, are raked out.

In smelting works, there ought to be at least three of these reducing furnaces which the oxidised products of the different operations can be reduced, viz., one for drosses, another for litharges, and a third for calciner's dross, to be described in next section. This necessity arises from the difference in the quality of the lead duced, and which, by being mixed, would afterwards entail an unnecessary expens

The dross is reduced in precisely the same way as the litharge, but when it is impure, the addition of a little soda-ash facilitates the operation and increases the duce of metal. The dross from the poor pans must also be kept distinct from tha the rich pans, as the difference in the contents of silver saves some expense in the sequent desilverisation of the two leads.

The same remark applies to the litharge, especially that which flows off towards conclusion of the cupellation.

The cost of reducing litharge and pot-dross is nearly the same, and the follow details may be taken as an average:

	s.	d.
Labour . . .	2	8·7
Coals, 4·1 cwt. . .	0	8·2
Repairs . . .	0	1·0
	3	5·9 per ton.

III. Softening of hard Lead.

All the lead produced at the blast-furnaces, and some leads obtained from poor in the reverberatory furnaces, are so hard from the presence of impurities or other ca as to render them unfit for treatment in the desilverising process. The lead obta from the English slag-hearth (p. 520) is also of the same character, and, until wi about the last twenty years, was sold for running lead-joints, &c., irrespective of contents in silver. The composition of some of these hard leads is given in the fol ing table:

Analyses of Hard Leads.

Authority.	Biewend.	Müller.		Richardson.	Kersten.	Bischoff					Streng.	Richardson.	Stre Ove
Locality	Altenauer.	Unterharz.	Okerhütte.	English.	Freiberg.	Holzapfel.	Katzenthal.	Villefort.	Pezey.	Pontgibaud.	Clausthal.	Spanish.	Lau terthal
Lead . .	83·91	84·72	82·40	99·27	91·51	81·27	91·40	95·60	93·00	91·4	85·34	95·81	83·65
Antimony .	16·01	10·32	10·04	0 57	5·32	16·40	8·20	2·40	7·00	8·2	14·06	3·66	16·00
Arsenic .	. .	2·00	3·00	.	1·02	. .	0·40	. .	. .	0·4			
Copper .	0·04	1·68	2·28	0·12	0·90	2·29	. .	traces	traces	. .	. .	0·32	0·13
Iron . }	0·04	0·88	1·08	0·04	0·62	0·04	. .	. .	. .	. .	0·10	0·21	0·30
Zinc . }												. .	
Sulphur .	. .	. .	. .	. .	0·20								

The writer having carefully examined the W B slag-lead, found that its hardness mainly due to the presence of antimony. He then suggested the erection of furnac which this lead, in a melted state, could be exposed to a current of hot air. The result the production of a good soft lead, at so reasonable a cost as to render the pro available as a regular operation in smelt mills.

Soon afterwards, the first cargoes of the now well-known Spanish hard lead arrive Liverpool; but the smelters there would not purchase them, and one cargo was t shipped to Newcastle-on-Tyne. This lead could not be softened in the brick furna being so fluid when melted, as to find its way out of the furnace in all directions. late Mr. G. Burnett, who consulted the writer on the subject, and witnessed the treatm of the slag-lead at Mr. Beaumont's works at Blaydon, then proposed the simple admirable plan of lining the furnace with a metal pan. Thus was laid the founda of a trade with Spain, which has gone on increasing, until, it is said, upwards of 20, tons of this description of lead are annually produced in that country.

Calcination of the Lead.

The furnace generally employed in this operation, termed *calcining* or *improvin* the workpeople, is represented in the *figs.* 625, 626 in elevation and vertical sect A is the fireplace; B, ash-pit; C, fire-bridge; D, cast-iron pan; E, flue; F

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G, a working door; and H, the spout for running
pan in pigs, or previously melted and ladled into

Fig. 625.

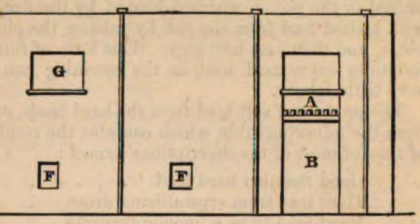
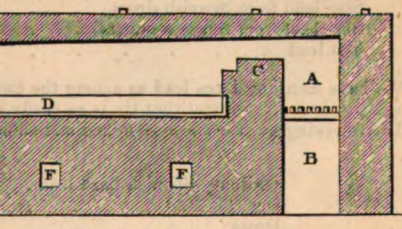


Fig. 626.



The charge varies from 6 to 10 tons, and the
upon the quality of the lead. With English slag
the writer has witnessed a charge of hard lead,
previous operations, require 30 days for softening.
working heat, the surface of the lead becomes
is removed by skimming, and withdrawn through
y impure, this dross floats in a semi-fluid state on

Fig. 627.

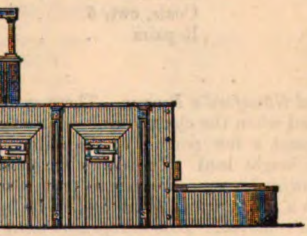
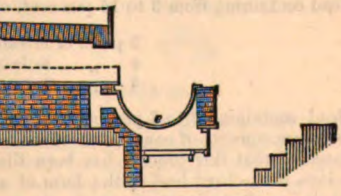


Fig. 628.



dried up with a little lime to bring it into a con-
The workman dips a ladle into the lead when he
lete, and pours it into a mould. The sample is

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examined when cold, and if it is soft to the scratch, with a flaky, crystalline appear on the surface, the contents of the pan are ready to be run off through the iron s into a pot on wheels, whence it is ladled into pig moulds.

An improvement has been made on the above simple form of furnace, which is sh in *figs.* 627, 628, representing a front view and a longitudinal section. The hard le melted in the pot, *a*, which is heated by the fire, *b*. The calcining pan, *c*, is sup with melted lead from the pot by raising the plug, *d*. The soft lead is run into pot, *e*, and then cast into pigs. This form of furnace possesses great advantages softening extra-hard lead, as the calcining pan can easily be kept always full, very little labour.

The produce of soft lead from the hard leads, of course, varies greatly, as will be from the following table, which contains the results of the treatment of many hund of tons of most of the descriptions named:

Good Spanish hard lead	93·2	per cent. soft lead.
Hard lead from crystallising dross . .	90·3	„ „
Hard lead from economic furnaces . .	84·3	„ „
English slag lead	87·1	„ „
Slag lead from Spanish dross . . .	66·9	„ „
Slag lead from refuse products . . .	67·3	„ „
Tea lead	76·4	„ „

We have mentioned tea lead as among the hard leads which can be treated by process, and we have found that tin is as easily separated thereby as antimony.

The following hard leads were mixed and submitted to calcination:

	tons.	cwt.
Ordinary Spanish hard lead . . .	1436	9
Ore slag lead	100	18
Dross „	69	12
Spanish „	60	9
Mill „	128	16
English „	75	15
Tea hard lead	9	15
Fume „	3	19
	tons 1885	13

At a cost, per ton, for:

	s.	*d.*
Labour . . .	2	5·3
Coals, cwt. 5 . .	0	10·0
Repairs . . .	0	1·6
	3	4·9

Pontifex and Glassford's Process.—These gentlemen employ the ordinary calc pan-furnace, and when the charge has been in operation for a few hours, the dross removed as usual, a few pounds of the following mixture is spread evenly ove surface of the bright lead. The doors are closed, and in about 10 to 20 minu brown or yellowish-brown cake collects on the surface. Fresh fuel is then throw the fire, and in a few minutes, when the smoke has cleared away, the doors are op and the cake is removed. This is repeated until the cake formed possesses a brig brown colour. When the alkaline mixture is used, with a charge of 9 or 10 to lead, about 55 lbs. are required during the 24 hours' operation. When the other ture is employed under the same circumstances, the quantity required varies bet 40 and 60 lbs.

The mixtures recommended are as follows:

1. For lead containing from 3 to 15 per cent. of antimony, the mixture consists

3 parts of nitrate of soda.
4 „ soda-ash.
4 „ burnt lime.

2. For lead containing 2 to 3 per cent. of antimony, and from ½ to 1½ per cen silica, the mixture consists of equal parts of soda-ash and caustic lime.

We understand that this process has been discontinued, and if it be true that antimony exists in the hard lead in the form of an alloy of antimony and lead, w when the whole is melted, rises to the surface in consequence of its lower specific gra we cannot see how the time of softening should be shortened with advantage, at the cost of so expensive an oxidising agent as nitrate of soda. In the old mode of work

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when the surface of the lead is kept constantly clear of dross by the calciner, the alloy, as it rises, is immediately oxidised by the current of hot air, whereas in this process, a considerable time is lost in allowing the mixture to act, and before the crusts are removed.

Mr. Barker of Sheffield has, however, succeeded in using the nitrate of soda and bisulphate of soda to advantage in this process, possibly from the fact that the impurities in his lead are so much smaller than in those of Spain, and by performing the operation, it is said, in crucibles.

Reduction of the Dross.

This process is performed in an ordinary reducing furnace, of smaller dimensions than usual, as the charges are smaller and require more attention to prevent the loss of antimony by volatilisation. The writer also introduced the use of a little soda-ash with the coal, when mixed with the dross, which was found to render the slag which is formed, more fusible, and enabled the workman to work at a lower heat. The following analyses of the hard lead obtained from this dross, with and without the addition of this flux, prove the advantage of its employment:

	Without the soda-ash.	With 2½ per cent. of soda-ash.
Lead	82·88	58·70
Antimony	16·09	40·66
Copper	0·68	0·32
Iron	0·35	0·32
	100·00	100·00

With the use of this flux, and continuing the calcining operation on the produce of the reducing furnace, the metals obtained were found to possess the following composition, according to the analyses of the writer:

English Hard Lead.

	Original lead.	1st calcination.	2nd calcination.
Lead	99·27	86·53	52·84
Antimony	0·57	11·29	47·16
Copper	0·12	traces	traces
Iron	0·04	0·34	traces
	100·00	98·16	100·00

Spanish Hard Lead.

	Original lead.	1st calcination.	2nd calcination.
Lead	95·81	64·98	56·60
Antimony	3·66	29·84	43·40
Copper	0·32	5·90	traces
Iron	0·21	0·20	traces
	100·00	100·92	100·00

It was found impossible to separate any soft lead from the product of the second calcination, all the metal becoming oxidised. This alloy is found of great use in casting type furniture, and in making some of the coarser kinds of type.

The cost of reducing the dross, per ton of lead produced, is as follows:

	s.	*d.*
Labour	5	2·1
Coals, 7·6 cwt.	1	3·2
Soda-ash, 34 lbs.	2	1·5
Repairs	—	
	8	6·8

Separation of the Antimony.

Instead of reducing the dross which yields the lead of the second calcination, the writer proposed to grind it to powder, and treat it with acetic acid, by which all the lead is dissolved, and yields sugar of lead by evaporation and crystallisation. The insoluble residuum, when reduced in the usual method employed for antimony ores, furnishes this metal very readily, and of fair quality.

The same process is applicable to the separation of the oxide of tin when the dross has been formed by treating tea lead.

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Cost of treating Spanish Hard Lead.

The Spanish hard-lead trade has assumed such an important development, in concluding this account of the treatment of hard lead, it may not be without interest to give the cost of extracting its silver, and preparing the soft lead for m

The cost of each item of expense is calculated on 20 cwt. of the original hard thus the second item is on 5 per cent less; the third, on 9 per cent.; the four 35½ per cent; the fifth, on 7 per cent. of the original lead; the seventh, eighth ninth items are an average on the whole work of the establishment. A similar ment has been published elsewhere, but in the absence of the above informati must have been unintelligible to most readers.

Cost of Softening and Refining Spanish Lead.

	£	s.	d.
1. Calcining	0	3	4·9
2. Crystallising	0	10	4·4
3. Refining	0	0	11·1
4. Reducing litharge and pot-dross	0	1	2·8
5. Reducing calcining dross	0	0	7·2
6. Smelting refuse products	0	0	4·2
7. Grinding materials	0	0	5·8
8. General labour	0	2	4·1
9. General charges	0	3	8·2
	£1	3	4·7

IV. Smelting of the Slags and other Products.

All the waste products resulting from all the previous operations—viz. ore o slags from the reverberatory furnace and ore-hearths, test-bottoms, litharge and cinders from the reducing furnaces, &c., are finally submitted to a process duction, in this country in a furnace known as the slag hearth, but abroad th generally mixed with poor lead-ores, and smelted in a blast furnace. We will de the method adopted in this country, and then select one of the continental plans illustration of the other method.

1. *The English Slag Hearth*

is known among the Germans as the *Krummofen*, or crooked furnace, and s the French as the *fourneau-à-manche*, or elbow-furnace. The general form construction of this furnace are shown in *figs.* 629, 630, &c. It somewhat resembl ore-hearth.

Fig. 629.

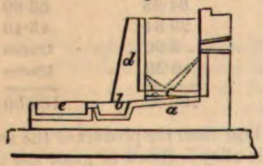
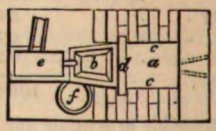


Fig. 630.



Hearth.—The sole-plate, *a*, is made of cast iron, and slopes slightly down to th hearth, *b*. There are strong cast-iron pieces, or *bearers*, *c c*, on each of the long s the sole-plate, which support the side walls as well as the cast-iron plate, or *forest* which forms the front of the shaft. The back is made of cast iron up to the hori tuyere in the middle, above which it is built of sandstone. A cistern, *e*, sta front of the fore-hearth, and a stream of water constantly flows through to gra the slag, and facilitate the subsequent separation of any pieces of lead dissem through it by washing. The lead flows over the fore-hearth into an iron pot, *f*, from below by a fire.

The bottom of the furnace is filled with small cinders, beaten down, and reach within 4 or 5 inches of the tuyere. The pot is also filled with similar cinders, filter the lead from the fusible slags which sometimes accompany the metal. then piled up above the bed of cinders, ignited, and the blast turned on.

When the peat is ignited, some coke is thrown in, and a layer of grey slag or refuse lead product is added. This is continued at intervals as the operation pro alternate layers of slag and fuel being added, metallic lead being produced, and a slag, free or nearly free from lead. The smelter occasionally forces a bent ir through the layer of cinder, to liberate the slag, which flows off into the water c

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y hard and impure, and is afterwards sent to the

nelting, it is often difficult to prevent the nose of
ong. The use of hot air prevents this inconvenience,
of this operation, as the following comparative

old air consumed 392 cubic feet of air per minute,

	£	s.	d.
. . . .	3	7	8
6d.	8	11	6
	11	19	2

t air, consumed 300 cubic feet of air per minute, and

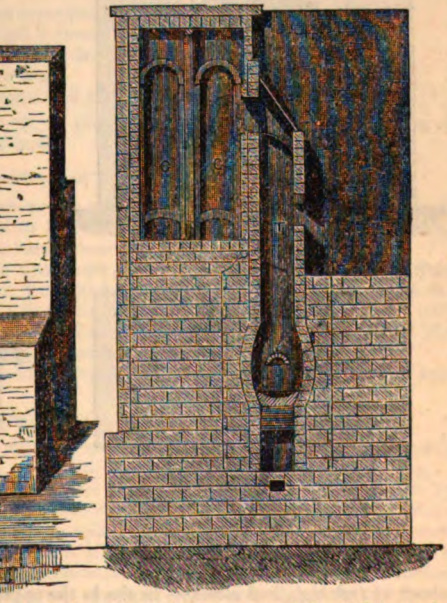
	£	s.	d.
. . . .	3	7	8
t. at 24s. 6d. . .	7	3	4
r, 11 loads at 1s. 8d.	0	18	4
	11	9	4

derable when hot air at 500° to 600° F. is employed.

lausthal Blast Furnace.

n 20 to 25 feet, with a diameter of 3 feet in the
ttom of the hearth projects beyond the blast of the
m in front. The lining of the hearth is made of
hollowed. This part is covered to some depth with
, with a gentle slope from the back to beyond the
ole enters at the lowest part of this basin, through

on a level with the floor, and at some distance from
supplied with air forced through the tuyeres at *t*.
Fig. 631.



owards the side of the tuyere, and the fuel towards
tuyeres cools the slags, and forms channels round
ng, which are called the "nose of the tuyere." The

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success of the operation greatly depends upon the proper management of this
these channels prevent the oxidation of the lead, which would give rise to the f
of fusible silicates of lead.

Under all circumstances, a large quantity of lead is volatilised, and the wh
vapours escaping from the tunnel-hole, T, pass through a series of chambers, C
entering the chimney, D. The fume which condenses is occasionally removed
the doors, *d*, and is again thrown into the furnace along with other products.

The scoriæ flow continuously into the fore-hearth, where they solidify
drawn down the inclined plane, *p*, by the workman, to the floor of the mill.
basin, *b*, becomes filled with metal, it is tapped into the reservoir, *a*.

The products which are collected in the outer basin consist of lead, upon
matt floats. This matt solidifies first, and is removed for further treatment,
lead is passed through a metal sieve, and cast into pigs.

The matt contains sulphides of lead and other metals, and when they accumul
are roasted in heaps to expel the sulphur; but so imperfect is the operation, t
portions must undergo as many as four roastings.

When the roasting is finished, the residue is smelted in the German sla
along with test-bottoms and other waste products. The *lit de fusion* is comp

32	parts	of roasted matt.
80	„	rich grey slags.
4·5	„	test-bottoms.
2	„	abstrichs.
2	„	litharge-cinders.
1	„	granulated cast iron.

The furnace used in the smelting of these products is shown in *figs.* 632—63

Fig. 632.

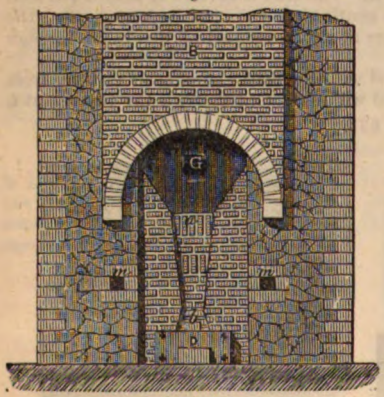


Fig. 634.

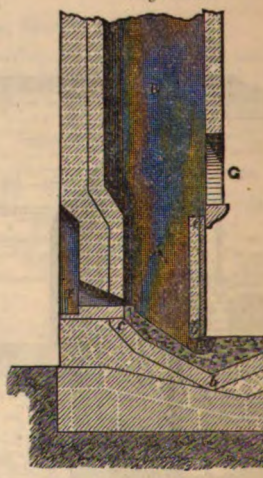
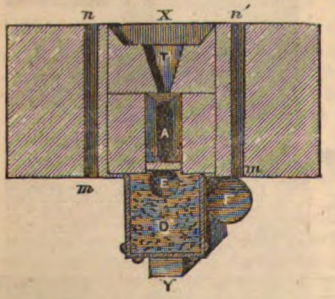


Fig. 633.



about 4½ feet high, and increases in size in the upper portion, C. *Fig.* 633, rep
horizontal section at the level of the tuyere, and *fig.* 634, a vertical section in the
It is blown with one tuyere, T. From the bottom of the furnace, which is *bra*
contents are drawn off by a tapping hole into the pot, F.

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The fuel employed is coke, and during the smelting, part of the iron of the matt combines with the silica of the slags and cinders, forming a new, very fusible slag. Another portion of the iron reduces the sulphide of lead, producing metallic lead and a second matt.

The following table contains the analyses of some slags made in smelting cupel bottoms, &c.:

Analyses of Lead-slags from Blast Furnace.

Authority .	Brüel.	Berthier.		Karsten.	Berthier.			
Locality .	Clausthal.	Poullaouen.		Harz.	Pontgibaud.			
Silica . . .	28·75	35·20	34·80	40·00	38·70	20·00	22·00	38·70
Oxide of lead . .	44·60	26·80	6·60	34·80	7·40	traces	35·60	16·00
Protoxide of iron .	6·87	19·40	34·40	5·60	28·40	37·90	4·20	23·70
Oxide of manganese .	0·42	0·60	0·60	3·00	2·40			
Suboxide of copper .	0·21	. .	. .	1·60				
Alumina . . .	8·92	4·60	4·80	12·90	8·70	10·00	5·20	11 60
Lime . . .	7·83	4·40	7·00	1·00	12·80	4·40	30·20	9·00
Magnesia . . .	0·53	. .	. .	0·90	0·60	. .	1·00	1·00
Teroxide of antimony	0·70							
Oxide of zinc . .	. .	5·20	0·50					
Protosulphide of iron	. .	2·20	9·00					
Sulphide of zinc .	. .	. .	. .	. .	. .	10·20		
Baryta . . .	. .	. .	. .	. .	. .	17·50		

This matt is treated in the same manner as before, but in the fourth matt the copper has accumulated to such extent, that it is called the *copper matt*, and is treated for that metal.

This accumulation of copper is always observed, however small the percentage of copper in the original ore. The copper, having a stronger affinity for sulphur than lead, goes on accumulating in these matts, and generally pays for its extraction.

The mixture smelted in these Clausthal furnaces, consists of:

34 parts of ore containing 24 of galena.
4 to 5 „ cupel bottoms.
1 „ the abstrichs from the refinery.
39 „ ore slags.
4½ „ granulated cast iron.

which mixture is stated, by Regnault, to produce 19 pts. of metal, and 7 or 8 pts. of the first matt, containing 2½ pts. of metal.

V. Condensation of the Lead Fume.

Since attention has been drawn to the great loss of lead in smelting its ores, numerous plans have been proposed to recover a portion of the metal in the form of fume, no fewer than sixteen patents having been enrolled for this object.

Where sufficient space exists, the plan most generally adopted is that of long flues and chambers. In some cases these flues extend for 5 miles. In Mr. Beaumont's extensive works, his able engineer, Mr. Sopwith, added nearly 5 miles of flue to one mill, the flue being 8 ft. high by 6 ft. wide. The saving in lead in these flues of Mr. Beaumont, is said to exceed £10,000 per annum.

Of the many plans which have been suggested, we will select two which are in successful operation.

1. *Stokoe's Condenser.*

This apparatus is represented in *fig.* 635, and has been found to answer remarkably well at Langley mill, as the details of an experiment, given on p. 525 amply prove.

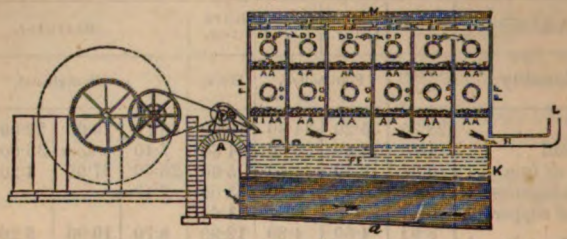
A is the top of the fume-flue; B is a wheel fixed in a metal case, set in motion by steam or water power, with a speed of 10,400 revolutions per minute, by which the fume is withdrawn from the flue and forced through the condenser. This condenser is rectangular, divided longitudinally by wooden rails, A, A, laid horizontally, on which a layer of pebble-stones, or other filtering material, is placed. The condenser is further separated into compartments, D. D, by the vertical divisions, C, C, which alternately reach the top, and dip below the surface of the water. The water flows from an open trough, M, divided crossways, immediately above D D, into the compartments, E, E, each of which is again subdivided by four or more low parallel partitions. The bottom

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of these cisterns, E E, is perforated. The water is supplied by a pipe, D G, a bottom of the condenser is kept filled with water to the level shown at F F.

The fume is withdrawn from the flue, and forced up and down through the beds, in the direction of the arrows, until the residual gases escape at H, i chimney, L. These fumes, in their passage through the condenser, come in with the water from E E, which is constantly falling in fine showers over the

Fig. 635.



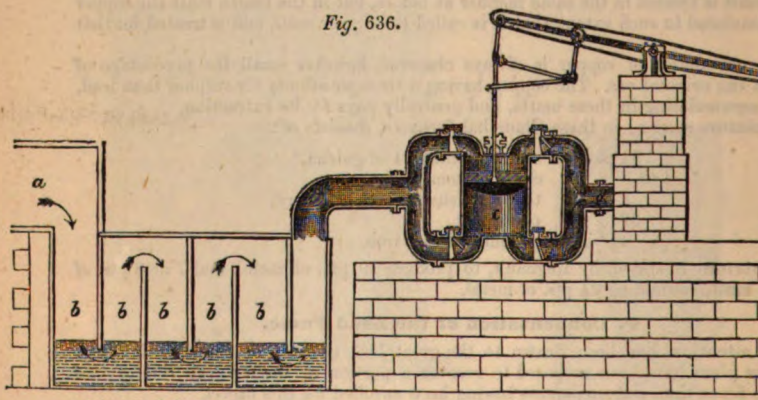
beds. The water carries down all the fume into the reservoir, F F, when occasionally drawn off at K.

The following table (p. 525) gives the results of an experiment, on the larg with one of these condensers.

Stagg's Condenser.

This apparatus is represented in *fig.* 636, in which *a* is the fume flue, *b b b b*, a constructed of wood or any other material, with partitions, dividing it alt

Fig. 636.



at top and bottom; *c*, one or more air-pumps, or exhausting machines; an exit-flue for the uncondensed gases. The air-pumps being set in motion, t is drawn through the water in the cistern, in which the metallic vapours densed, so perfectly, that the writer has walked along the exit-flue without bei with a single particle of fume. The passage of the vapours under the water c great agitation and spraying of the water, which materially assists in the co tion. When the water becomes charged with fume, it is drawn off by cocks, into tanks to allow the fume to subside.

Mr. Stagg has drawn up the following table from his experiments, to s annual saving of lead which may be effected by his condenser, and the vo gases for which the exhausting apparatus must be constructed:

Nature of furnace.	Quantity of lead operated upon or produced per annum.	Volume of smoke emitted from such furnace per minute.	Annual sa effected on ea ration in
	tons.	cubic feet.	tons.
Ore hearth . . .	250	1,000	12½
Reverberatory . .	500	1,500	20
Refining and reducing.	500	1,500	35
Slag hearth . . .	200	3,000	40

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Total weight of lead refined	37,632	or	16	0	0	0	. .	. .	288	0	0	Refining Process.						
Produce of lead from litharge	32,592	or	13	18	0	0	. .	. .	249	8	7	Taken from condenser.						
												Produce of lead from condensed fumes	2,375	or 1	0	0	23	47	. .	18	3	6
Total loss of lead and value in refining . . .	5,040	or	2	3	0	0	13·40	. .	38	11	5											
Reducing Process.												Reducing Process.						
Total weight of dross reduced	43,008	or	18	6	0	0	. .	. .	329	2	0	Taken from condenser.						
Produce of lead from the dross	41,468	or	17	13	1	0	. .	. .	317	6	0	Produce of lead from condensed fumes	725	or 0	6	1	25	47	. .	5	10	6
Total loss of lead and value in reducing . . .	1,540	or	0	13	3	0	3·60	. .	11	16	0											
Loss in blast hearth process							. .	. .	178	15	5	Saved from blast hearth process						. .	. .	84	5	0
„ „ refining „							. .	. .	38	11	5	„ „ refining „						. .	. .	18	3	6
„ „ reducing „							. .	. .	11	16	0	„ „ reducing „						. .	. .	5	10	6
												Balance in long flue slags &c., as proved by actual experiment.						. .	. .	121	3	10
									229	2	10									229	2	10

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The composition of the fumes produced from different operations and lo
given in the following tables:

TABLE I.—*Analyses of Fumes from the Reverberatory Furnaces.*

Locality	Pontgibaud.		Alston Moor.	Conflans.	Redruth.	
Authority	Berthier.	Rivot.	Berthier.			Ra
Protoxide of lead	11·00	. .	10·20	42·60	71·20	
Sulphate of lead	60·00	39·00	65·60	39·00	. .	
Arsenious acid	2·00	1·50				
Sesquioxide of iron	12·00	. .	3·40	. .	traces	
Oxide of zinc	15·00	2·70	13·80	. .	. .	
Carbonate of lead	. .	35·00	. .	. .	. .	L
Sulphate of zinc	. .	2·30	. .	. .	. .	
Sulphide of lead	.	4·50	1·40			
Oxide of copper	. .	. .	. .	. .	0·20	
Alumina	. .	. .	. .	. .	1·20	
Silicic acid	. .	13·20	5·60	17·40	20·60	
Clay	. .					

TABLE II.—*Analyses of Fume from the Refinery.*

Locality	Pontgibaud.		Villefort.
Protoxide of lead	88·20	40·00	71·20
Sulphate of lead	9·00	20·00	
Arsenious acid	0·30	3·00	17·80
Oxide of antimony	4·40	. .	. .
Oxide of zinc	. .	. .	. .
Oxide of bismuth	. .	. .	. .
Carbonate of lime	3·70	17·00	
Carbonic acid	. .	. .	5·00
Silicic acid	3·40	20·00	4·60
Clay			

TABLE III.—*Analyses of the Fumes from the Blast Furnaces.*

Locality	Freiberg.	Pontgibaud.			Hal brüc
Oxide of lead	27·90	10·00	66·50	3·70	1·
Sulphate of lead	13·00	47·00	. .	13·00	.
Arsenious acid	2·10	. .	1·10	1·50	.
Sesquioxide of iron	. .	. .	3·00	13·00	
Oxide of zinc	49·50	10·00	12·00	3·10	95·
Carbonate of lime	. .	. .	. .	. .	.
Carbonic acid	7·00				
Sulphuric acid	. .	. .	17·00		
Silicic acid	. .	33·00	. .	. .	1·
Sulphur	. .	. .	. .	8·90	
Metallic lead	. .	. .	. .	55·40	

T.

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LEAD, ALLOYS OF. Lead forms alloys with several metals by simple fusion, and many of these alloys are definite chemical compounds, which produce mechanical mixtures when fused with either of the constituents in excess. This latter fact has given rise to the metallurgical operation of eliquation.

1. With Antimony.—Lead alloys itself with this metal in several proportions, and the alloys are harder, more tender, and oxidise more easily than lead; they are also more fusible, as well as harder than either metal.

An alloy of equal parts of the two metals is porous and brittle: 2 pts. of antimony with 1 pt. of lead produce a very hard alloy, capable of receiving a fine polish, and used to make the keys of wind instruments; 3 pts., and even 4 pts. of antimony to 1 pt. of lead produce a hard but malleable alloy. An alloy of lead and antimony is used in making *type-metal*, a little zinc being sometimes added. Some type-founders add ¾ pt. of tin, but this addition is only suitable for stereotype plates. The plate on which music is printed is composed of 12 pts. tin, 7 lead, and 1 antimony. The ordinary composition of type-metal is 83 pts. lead and 17 antimony.

Emery wheels and grinding tools for the lapidary are formed of an alloy of antimony and lead.

Mr. Jas. Nasmyth has suggested the use of lead as a substitute for all works of art hitherto executed in bronze or marble. He states that the addition of 5 per cent. of antimony gives it not only hardness, but greater capability to run into the most delicate parts of the work. An alloy of this description, analysed by Karsten, and corresponding with the formula Pb^9Sb, was found on the hearth of a smelting furnace at the Mulder Works: it contained 90·10 p.c. Pb, 6·48 Sb, 1·42 Zn, 1·50 Cd, 0·24 Ag, and traces of Ni, As, and S.

2. With Arsenic.—The presence of this substance renders lead brittle, greyish white, and very fusible. The application of heat expels a portion of the arsenic, but the remainder resists the highest temperature.

This alloy constitutes the metal of which shot are cast, 40 lbs. of metallic arsenic being mixed with 20 cwt. of lead. It also exists native at Clausthal in the Hartz, and is composed of 67·63 p.c. Pb, 24·19 As, 4·41 mispickel FeAsS, 2·26 Fe, 0·54 S, and 0·7 Co.

3. With Bismuth.—This metal unites with lead in all proportions, with condensation. Some of the alloys are more malleable than lead, but the malleability diminishes as soon as the quantity of bismuth equals that of the lead.

When 3 at. lead are united to 2 at. bismuth, the mixture has only one solidifying point, viz. 129° C., but in PbBi, this point is 146°; in $PbBi^2$ it is 143°, and with Pb^2Bi^2 the temperature is between 163° and 171°.

These alloys have no special application in the arts, but they are used to adulterate mercury. An alloy of 1 pt. lead, 1 pt. bismuth, and 3 pts. mercury, is really an amalgam, which is sufficiently fluid to pass through chamois leather.

An amalgam of 2 pts. bismuth, 4 pts. lead, and 1 pt. mercury, is solid in the cold, but when pieces of it are rubbed together, they immediately melt.

Lead and bismuth occur associated in nature, in the mineral *Kobellite*, already described (p. 448).

4. With Bismuth and Antimony.—When antimony is added to the previous alloy in quantity equal to the bismuth, a metal is obtained which expands on cooling. Advantage is taken of this in casting stereotype plates. This alloy, according to Mackenzie, contains 70 p.c. lead, 15 antimony, and 15 bismuth.

5. With Chromium.—The alloy which contains 0·25 of chromium is fusible at 150° C., ashy-grey, but whiter than lead. It can be hammered into thin sheets, which are very brittle. Nitric acid dissolves the lead without attacking the chromium.

6. With Copper.—The alloys of lead and copper are difficult to prepare and to preserve at a high temperature. The copper must be introduced into a bath of lead heated above redness, and the alloy rapidly cooled; even then some portions are reddish-coloured, indicating the commencement of a disunion of the elements. If the alloy is heated to the melting point of lead, the latter abandons the copper, which is left in the form of a porous mass.

The process of eliquation is founded upon this fact, and as the silver present in the copper has a great affinity for the lead, the latter carries off the silver, which is separated in the manner already described (ii. 32).

In smelting sulphide of copper containing sulphide of lead, the latter metal passes off in great measure in the scoriæ in the first operations, but is found in the copper of the subsequent treatment.

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There would appear to be two alloys of these metals, one containing m and melting at a higher point than the other, which contains more lead.

Small quantities of lead diminish the ductility of copper at ordinary te and at a red heat. Copper containing even 0·1 per cent. of lead, may still ordinary purposes, but it cannot be formed into thin sheets or wire.

The alloy of 4 pts. of lead to 1 pt. of copper is employed for casting lar types.

7. With Manganese.—When a mixture of 892 pts. of protoxide of ma 2789 pts. of litharge are heated with a little charcoal in a charcoal-line homogeneous, compact, and ductile alloy is obtained, which can be rolle sheets of great lustre.

8. With Mercury.—This metal is easily alloyed with lead, either by the former into the latter in a melted state, or by triturating lead filin mercury.

The amalgam possesses a brilliant white colour, and still remains with as much as 33 per cent. of lead, but it soils the fingers. The amalg parts can be crystallised, and a piece of lead plunged into this amalg covered with crystals when it is withdrawn.

The amalgam has a higher specific gravity than either of the metals, c contraction which they undergo in combining.

The presence of 0·0002 to 0·00025 of lead improves the mercury for use ters and thermometers, as the latter metal has then not so great a tende globules on the convex surface of the glass.

9. With Mercury and Antimony.—Wetterstedt has found that the a small quantity of mercury to the alloy of antimony and lead removes t of this metal to oxidation. He has proposed to use the triple alloy as a s ships. It is composed of 94·4 per cent. lead, 4·3 antimony, and 1·3 mer said not to be so rapidly encrusted with barnacles, &c. as copper sheath

10. With Potassium and Sodium.—The alloys of lead with these formed when a reducing alkaline flux is fused with oxide of lead, as first Vauquelin; and Serullas has described the properties of one of these allo when 100 pts. of litharge are strongly heated with 60 pts. of cream of t alloys can also be prepared directly; that containing 25 per cent. of it potassium is brittle, with a coarse-grained fracture. A similar alloy wit bluish and malleable, but that with one-third of sodium is brittle. T distilled with the iodides of ethyl, methyl, &c., yield the lead-compounds of radicles. (See LEAD-RADICLES, ORGANIC, p. 560.)

11. With Tin.—Lead may be fused with this metal in all proportions, but of the resulting mixtures does not correspond with the specific gravities metals. The following table contains the results of Kupffer's experiment

Composition of the Alloys.	Specific Gravity.			M P
	Found.	Calculated.	Difference.	
Lead, pure .	11·3803	. .	. .	3
Tin, pure . .	7·2911	. .	. .	2
SnPpb* . .	9·4263	9·4366	0·0103	2
$SnPpb^2$ . .	10·0782	10·0936	0·0154	
$SnPpb^3$ . .	10·3868	10·4122	0·0254	2
$SnPpb^4$ . .	10·5551	10·6002	0·0431	
$PpbSn^2$ . .	8·7454	8·7518	0·0064	1
$PpbSn^3$ . .	8·2914	8·3983	0·0069	1
$PpbSn^4$ . .	8·1730	8·1516	0·0096	1
$PpbSn^5$ . .	8·0279	8·0372	0·0093	1
$PpbSn^6$ . .	7·9210	7·9526	0·0116	

The lead, so soft in itself, has the singular property of increasing the the tin: it slightly darkens the colour, gives a grained fracture, and caus liar creaking sound, produced on bending tin, to disappear.

The alloys of lead and tin are distinguished by the facility with which and burn. The alloy of 4 or 5 pts. of lead and 1 pt. tin burns like charc heat, the combustion continuing like that of an inferior peat, with the f

* Sn = 118 : Ppb = 207.

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cauliflower excrescences. This action appears to be due to the affinity which exists between the two oxides. The oxides so formed, when fused either alone or with silica and an alkali, produce a white opaque *enamel* used for *dial-plates*, &c., and also in earthenware.

The *solders* used by plumbers vary much in composition, but there are three commonly known as *fine solder*, composed of 2 pts. of tin and 1 pt. of lead; *common solder*, containing equal pts. of each metal; and *coarse solder*, composed of 2 pts. of lead to 1 pt. of tin. Tomlinson gives the following table of the composition of these alloys and their melting points:—

	Tin.	Lead.	Melting Point.		Tin.	Lead.	Melting Point.
No. 1.	1	25	558°	No. 7.	1½	1	334°
„ 2.	1	10	541	„ 8.	2	1	340
„ 3.	1	5	511	„ 9.	3	1	356
„ 4.	1	3	482	„ 10.	4	1	365
„ 5.	1	2	441	„ 11.	5	1	378
„ 6.	1	1	370	„ 12.	6	1	381

No. 5 is also called plumber's *sealed solder*, which is assayed in the same way as pewter, and then stamped by the officer of the Plumbers' Company. No. 8 is used for soldering cast iron and steel, sal-ammoniac or common resin being used as flux. This alloy is also used for tinned iron, with chloride of zinc or resin as the flux. Gold and silver are also soldered with No. 8, and Venice turpentine for a flux. The same alloy is used with copper, brass, gilding metal, gun metal, &c., and sal-ammoniac, chloride of zinc, or resin as the flux; with zinc, and chloride of zinc as flux; with lead and tin pipes, with a mixture of sweet oil and resin as flux; with Britannia metal, and chloride of zinc or resin as flux. The alloys 4 to 8 are used for ordinary plumber's work, with tallow as flux.

Pewter is another alloy of these metals, and the trade in this article is so important in this country, that the pewterers have formed an incorporated company ever since 1474.

Common pewter is composed of 80 pts. of lead and 20 pts of tin, but other metals are sometimes added, such as copper, antimony, and zinc. The manufacturers of pewter state that a better pewter is obtained by working up old pewter with fresh ingredients.

Holtzapfel gives the following account of these alloys:—"Some pewters are now made as nearly as common as that of equal parts of the metals: when cast they are black, shining, and soft; when turned, dark and bluish. Other pewters only contain ⅛ or ¼ of lead; these, when cast, are white, without gloss, and hard; such are pronounced very good metal, and are but little darker than tin. The French legislature sanctions the employment of 18 per cent. of lead with 82 per cent. of tin, as quite harmless in vessels for wine and vinegar. The finest pewter, frequently called *tin and temper*, consists mostly of tin, with a very little copper, which makes it hard and somewhat sonorous, but the pewter becomes brown-coloured when the copper is in excess. The copper is melted, and twice its weight of tin is added to it, and from about ½ to 7lbs. of this alloy, or the *temper*, are added to every block of tin weighing from 360 to 390lbs. Antimony is said to harden tin, and to preserve a more silvery colour, but is little used in pewter. Zinc is employed to cleanse the metal, rather than as an ingredient. Some stir the fluid pewter with a thin strip, half zinc and half tin; others allow a small lump of zinc to float on the surface of the fluid metal, while they are casting, to lessen the oxidation."

Plate pewter is the hardest, and is used for making plates and dishes. The pewter called *trifle* is used for beer-pots, and *ley* for the larger wine measures.

Pewter wares are formed either by hammering or by casting, plates and dishes being hammered, while measures and spoons are cast. Pewter is also made in the form of sheets for engraving cheap music, the softness of the metal allowing the notes to be formed by means of punches, instead of engraving with a burin.

Lapidaries, jewellers, and watchmakers use laps and polishers of pewter.

Although lead is so poisonous a metal, it can be employed in domestic utensils, when alloyed with tin, which would appear to neutralise this action of the lead. In an alloy of 3 pts. of lead and 1 pt. of tin, Proust and other chemists have found that vinegar dissolves out nothing but the tin; but for domestic utensils, Vauquelin has shown that the lead ought not to exceed 17 or 18 per cent. An alloy of 3 pts. of lead and 5 pts. of tin is used for tinning certain articles of copper.

The *brilliants of Fahlun* are made with an alloy of 19 pts. of lead and 29 pts. of tin, which are fused together and allowed to cool for a short time. At this point the alloy adheres to a glass tube cut into facets, on which it is allowed to solidify, and

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from which it can afterwards be easily removed. A lens plunged into this al
a brilliant mirror.

These alloys form superior baths in which to temper various articles of
following table contains all the information on the subject:—

Alloy.		Temperature.		Objects to be tempered.
Lead.	Tin.	C.	F.	
14	8	213·4°	415·4°	Lancets.
15	8	221	429·8	Other surgical instruments.
16	8	225	437	Razors.
17	8	240	464	Penknives, scalpels, cold-chisels.
28	8	257	494·6	Shears, gardeners' tools.
38	8	262	503·6	Hatchets, axes, planes, dressmakers'
60	8	275	527	Table-knives, large scissors.
96	8	284	543·2	Swords, watch-springs, &c.
100	8	289	552·2	Strong springs, poniards, augers, saws, &c.

For higher temperatures recourse must be had to other baths.

Alloys of lead and tin are also employed in making anatomical injections.

12. With Tin and Bismuth.—These ternary compounds are well kno
the name of *fusible alloys*. They melt at low temperatures, some even below
of boiling water. This is one cause why they are so rarely obtained in a
homogeneous condition.

There are several of these alloys known by the name of the first observer;
following all melt below the boiling point of water:

Observer.	Lead.	Bismuth.	Tin.	Melting po
Homberg. . .	1	1	1	122·00
Rose . . .	1	2	1	93·75
Newton . . .	5	8	3	94·44
Lichtenberg . .	2	5	3	
Krafft . . .	2	5	1	104·00

In whatever proportions the three metals are mixed, they exhibit one fixed s
point, at 98° C., and two higher points which are variable.

When 120 lbs. of an alloy, consisting of 3 pts. tin, 2 lead, and 5 bismuth, ar
they yield, on cooling, tolerably definite crystals, which melt below 100° C.,
tain nearly equal numbers of atoms of the three metals, or 15·76 per cent.
lead, and 57·68 bismuth.

The melting point of fusible metal is raised by the addition of potassium.

This alloy presents many anomalies in its dilatation and contraction; th
temperature from zero up to 35° C., the volume increases in the prop
100 : 100·83, and it diminishes up to 56° C. in the ratio of 100·83 : 99·13, wh
point of greatest density; it then begins to expand. It is remarkable
maximum volume, reached at 35° C. is the same as that which it possesses
which is the melting point of Rose's alloy.

It is impossible to determine the melting point of these alloys except by exp
thus, in Newton's fusible metal, which melts between 198° and 200° F., the th
point ought to be 520°, as shown by the calculation,

$$\frac{8\text{Bi} \times 500° + 5\text{Pb} \times 600 + 3\text{Sn} \times 442}{16} = 520° \text{F.}$$

The following table contains the melting points of various alloys of the
metals:

Bismuth.	Lead.	Tin.	Melting point.	Bismuth.	Lead.	Tin.	Mel
8	12	8	130·90° C.	8	8	8	12
8	5	3	94·44	8	10	8	12
8	6	3	97.78	8	16	8	14
8	8	3	109·64	8	16	10	14
8	8	4	112 20	8	16	12	14
8	8	6	116·05	8	16	14	13

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Bismuth.	Lead.	Tin.	Melting Point.	Bismuth.	Lead.	Tin.	Melting Point
8	16	16	140·80° C.	8	28	24	163·00° C
8	16	18	144·10	8	30	24	170·50
8	16	20	147·40	8	32	24	176·00
8	16	22	152·80	8	32	28	165·00
8	16	24	154·00	8	32	30	163·90
8	18	24	152·90	8	32	32	158·40
8	20	24	151·90	8	32	34	157·30
8	22	24	151·80	8	32	36	158·40
8	24	24	152·90	8	32	38	159·50
8	26	24	158·40	8	32	40	160·60

It is remarkable that the tin, which melts below the fusing points of both lead and bismuth, should raise the melting point of these alloys.

These alloys are of great value in regulating the tempering of delicate articles of cutlery. They are also used for taking impressions of medals, bas-reliefs, and on the Continent for producing casts of metals by the *clichè* process. They can also be employed to take casts from the surface of wood and embossed paper. Beautiful casts of the internal ear, showing the complexities of its bony cavities, have been made with them; also cake-moulds for the manufacture of toilet soaps.

Two of these alloys are well known in this country under the names of *Britannia metal* and *Queen's metal*. The former is composed of equal parts of brass, tin, antimony and bismuth; the latter of 1 part each of antimony, lead and bismuth, with 9 parts of tin. Both are used for making teapots, spoons, &c.

A safer and better alloy is said to be made by adding to 100 pts. of French pewter, 5 pts. antimony and 5 pts. brass, to harden it.

In Birmingham, teapots, milk-jugs, &c. are made into form by a process called *spinning*, which consists in bringing the sheet of pewter against a rapidly revolving tool, by which, with a little dexterity on the part of the workman, it is gradually fashioned.

13. With Tin, Mercury, and Bismuth.—The addition of mercury to the three metals forming the previous alloys renders them much more fusible, and communicates some new properties.

D'Arcet's alloy, similar to Newton's, when amalgamated with mercury, melts at 45° C. This alloy or amalgam is specially valuable in making anatomical preparations. It is introduced into the parts of the body in the liquid state, and allowed to solidify. The flesh and other animal matters are afterwards dissolved and removed by a strong solution of potash.

The interior of glass tubes, globes, &c. are tinned by means of this amalgam, which is poured into the vessel by means of a funnel, in the liquid state, and gently agitated. The surplus is then poured off, and the operation is complete. Glass of different colours is employed, and objects of great beauty are thus easily prepared.

The best compound is composed of 1 pt. lead, 1 tin, 2 bismuth, and 10 mercury. The first three are fused together, and then the mercury is added.

14. With Tin and Copper.—An alloy of these metals was used by the Romans for casting statues, &c. It was formed of 67·12 per cent. natural bronze, 22·37 old bronze, 5·25 tin, and 5·26 lead.

Bronze is made of copper and tin, to which some manufacturers add a little lead, and in the analyses of several ancient coins by Phillips, lead appears to have been an important constituent. (See Table, vol. ii. p. 45.)

When lead is mixed with copper in the proportion to 6 to 1, ordinary pot-metal is formed, called *dry pot-metal*, a quality which is characteristic of these alloys.

British bell-metal consists of 5·6 per cent. zinc, 10·1 tin, 4·3 lead, and 80·0 copper.

Biddery ware is made in India by combining 2 pts. of tin, 4 pts. lead, and 16 pts. copper, and is afterwards melted in the proportion of 3 pts. to 16 pts. of zinc.

The other alloys of copper to which small quantities of lead are added are described in another part of this dictionary.

15. With Zinc.—This metal communicates hardness to lead, and the property of receiving a fine polish, without diminishing the malleability. The two metals may be fused in any proportion, but the alloys are all decomposed at a white heat, the zinc being volatilised, and carrying off with it large quantities of the lead.

The presence of lead in zinc, however, is said to be injurious to the latter metal when rolled into sheets, diminishing its elasticity and probably its tenacity.

When equal quantities of *lead*, *zinc*, and *bismuth* are fused, an alloy is obtained which melts in boiling water.

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The alloy of *lead*, *tin*, and *zinc*, $ZnSn^9Pb^2 = ZnSn^3.2PbSn^3$, has but one point, viz. at 168° C., but all other alloys have also two higher points, *b* a

Atoms.			Solidifying points.		
Zinc.	Tin.	Lead.*	*a.*	*b.*	*c.*
3	11	2	168°	. .	182°
1	6	1	168	171°	204
1	9	1	168	178	183
1	9	2	168		
1	12	2	168	. .	178
1	12	3	168	172	
1	18	4	168	172	178
1	21	6	168	. .	175
1	33	10	168	. .	178

LEAD, ANTIMONIDE OF. (See p. 532.)

LEAD, ARSENIDE OF. (See p. 532.)

LEAD, BROMIDE OF, $PbBr^2$, is obtained by the same processes as t which it resembles in crystalline form. It is somewhat less soluble in melts out of contact with air, at about the same temperature as the chloride horny mass. By fusion, in contact with the air, it is converted into a ba or oxybromide. It unites with the bromides of potassium and sodium, for talline double salts, which, however, are decomposed by water.

Acetobromide of lead, $Pb''Br^2.Pb''(C^2H^3O^2)^2$, or *Plumbobromacetin*,

is obtained like the corresponding chlorine-compound (p. 539), which it reser properties and reactions. (Carius.)

LEAD, BROMOCARBONATE OF. An insoluble compound, p boiling together equivalent quantities of bromide and carbonate of lead readily, and when further heated gives off carbonic anhydride, and leav bromide of lead.

A *bromophosphate* and *bromophosphite of lead* may be formed in like man

LEAD, CHLORIDE OF. $PbCl^2$, *Magisterium plumbi*, sometimes ca *lead*.—Lead unites but slowly with chlorine, the combination not bein with visible combustion; it is also but slowly attacked by hydrochloric only when in contact with the air; on the application of heat, it dissol with evolution of hydrogen. The chloride is prepared by boiling the pr carbonate, or sulphide of lead, with water, into which hydrochloric acid is drop as the resulting chloride of lead continues to dissolve, or by adding hydroc or chloride of sodium to a concentrated solution of a lead-salt. Chloride o also been found, as a natural product, called cotunnite, in the crater of after the eruption of 1822, mixed with chloride of sodium, and chl sulphate of copper. This native chloride occurs in trimetric crystals, $\infty P : \infty P = 99° 46'$; $oP : \breve{P}\infty = 149° 14'$; and the ratio of the prin brachydiagonal and macrodiagonal, is as 0·5953 : 1 : 1·1868. The obser are ∞P, $\infty\breve{P}\infty$, $\infty\dot{P}\infty$ $2\dot{P}\infty$, $\dot{P}\infty$. Also acicular crystals. It is soft enc scratched by the nail, and has a specific gravity of 5·238. Lustre adamanti ing to silky or pearly. Colour white. Streak white. (Dana, ii. 97.)

Chloride of lead dissolves in 135 pts. of cold water, in less than 30 pts. water, and separates from the solution in long, flat, needle-shaped crystal solves in pure water, and in strong *hydrochloric acid* more easily than in acid, and therefore separates from the acid solution on moderate dilution w and from the saturated aqueous solution, on addition of hydrochloric acid. somewhat soluble in weak alcohol, very sparingly in alcohol of 76 per cent soluble in alcohol of 94 per cent. Its solubility in water is greatly diminish presence of chloride of calcium. In solutions of alkaline hyposulphites, or of sodium, on the contrary, it is much more soluble than in water, so that, a solution of 190 pts. acetate of lead with 58·5 pts. chloride of sodium, onl pts. of lead-chloride are precipitated, whereas 139 pts. are formed. A solut chloride in strong hydrochloric acid is not precipitated by *sulphydric acid*, l dition of water, precipitation immediately takes place. A solution of lea mixed with aqueous sulphydric acid containing hydrochloric acid, forms a reddish-brown precipitate of sulphochloride of lead (p. 559). An aqueous s the chloride mixed with sal ammoniac is not precipitated by sulphuric acid.

Chloride of lead melts when heated out of contact with air, and may be though with difficulty; the fused mass solidifies on cooling, to a white t

* Atomic weight of zinc = 65; of tin = 118; of lead = 207.

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fissured mass of specific gravity 5·8, formerly called **horn-lead**. When heated in contact with the air, it fumes strongly before the heat rises to redness, then turns yellow, and is converted into an oxychloride (p. 555). When it is heated in a stream of *carbonic oxide*, chloride of carbonyl (phosgene) $COCl^2$, is formed, and metallic lead is separated (Göbel). It quickly absorbs *ammonia-gas*. When it is moderately heated in *phosphoretted hydrogen gas*, hydrochloric acid is given off, phosphorus distils over, and metallic lead remains. A solution of *hypochlorous* acid converts it into peroxide of lead.

Acetochloride of lead, $Pb''Cl^2.Pb''(C^2H^3O^2)^2$, or *Plumbochloracetin*, $\begin{matrix} C^2H^3O \\ Pb'' \end{matrix}\Big\}\begin{matrix} O \\ Cl' \end{matrix}$ is obtained in monoclinic crystals, by mixing recently precipitated chloride of lead with acetate of lead, and a sufficient quantity of glacial acetic acid to form a viscid mass, which solidifies in a short time, and either freeing this mass from excess of acetic acid by pressure, or heating it in a sealed tube to 130° or 140°;—or together with acetate of ethyl, by the action of acetate of lead on chloride of ethyl. It dissolves, though with difficulty, in acetic acid without decomposition, but is decomposed by water, with separation of a small quantity of lead-chloride, and formation of the compound $Pb''Cl^2.3Pb''(C^2H^3O^2)^2$ or $\begin{matrix} (C^2H^3O)^2 \\ Pb^3 \end{matrix}\Big\}\begin{matrix} O^2 \\ Cl' \end{matrix}$ which dissolves in the water, and may be recrystallised without decomposition. It is decomposed, however, by glacial acetic acid, which leaves the original compound. The compound, $\begin{matrix} C^2H^3O \\ Pb'' \end{matrix}\Big\}\begin{matrix} O \\ Cl' \end{matrix}$ is analogous to glycolic chloracetin, $\begin{matrix} C^2H^3O \\ (C^2H^4)'' \end{matrix}\Big\}\begin{matrix} O \\ Cl \end{matrix}$ (ii. 568), and may therefore be called **plumbochloracetin**. (**Carius**, Ann. Ch. Pharm. cxxvii. 87.)

LEAD, CHLOROCARBONATE OF. $2PbCl.Pb^2CO^3$, or $\begin{matrix} (CO)'' \\ Pb^2 \end{matrix}\Big\}\begin{matrix} O^2 \\ Cl^2 \end{matrix}$.—This compound is produced as a white insoluble powder, by boiling 1 at. carbonate of lead with 2 at. (or more) of the chloride, and water. It also occurs native, though rarely, as **corneous lead** or **kerasin**, in acute quadratic pyramids in which P : P in the lateral edges = 113° 48′, and in the terminal edges = 107° 22′. Observed faces $\infty P\infty$, P, ∞P, P and others. Cleavage distinct parallel to ∞P. The mineral likewise occurs in botryoïdal and stalactitic forms. Hardness = 2·5 to 3·0. Specific gravity = 6·0 to 6·1. Colour white, grey, and yellow. Streak white. Transparent to translucent. Fracture conchoïdal. Rather sectile. It occurs at Crawford, near Matlock in Derbyshire, in minute crystals at a lead mine near Elgin in Scotland, and at Tarnowitz, in Upper Silesia, where also large pseudomorphs of lead-carbonate (cerusite) in the form of this mineral are found.

Both the natural and the artificial compound fuse readily, and are converted at a higher temperature, with loss of 7·5 per cent. CO^2, into the oxychloride, $PbCl^2.PbO$.

LEAD, CHLORIODIDE OF. Obtained in pale yellow four-sided needles, from a solution of the iodide in boiling hydrochloric acid; it is gradually decomposed by water, which extracts the chloride of lead. (**Labouré**, J. Pharm. [3] iv. 328.)

LEAD, CHLOROFLUORIDE OF. PbClF.—Formed by precipitating aqueous fluoride of sodium with a boiling solution of chloride of lead, or with a mixture of acetate of lead and chloride of sodium. It is a white powder, which melts when heated, without giving off water or acid. Dissolves in water without decomposition, and easily in nitric acid. (**Berzelius.**)

LEAD, CHLOROPHOSPHATE OF. When a boiling solution of chloride of lead is poured into a boiling solution of phosphate of sodium, the latter being in excess, a precipitate containing $PbCl^2.Pb^3(PO^4)^2.H^2O$ is formed, insoluble in water, but soluble in nitric acid, which converts it into a nitrophosphate (**Heintz**, Pogg. Ann. lxxiii. 122). When, on the contrary, a boiling solution of phosphate of sodium is poured into an excess of chloride of lead, a precipitate is formed which, according to **Heintz**, is composed of $PbCl^2.2Pb^3(PO^4)^2$, but according to **Gerhardt** (Ann. Ch. Phys. [3] xxii. 505), of $PbCl^2.Pb^2H^2(PO^4)^2$. The same compound is formed when a soluble phosphate is precipitated by a lead-solution in presence of a soluble chloride.

The compound $PbCl^2.3Pb^3(PO^4)^2$ occurs native as **pyromorphite**, sometimes pure, sometimes having part of the phosphorus replaced by arsenic, sometimes associated with fluoride and phosphate of calcium. (See **Pyromorphite.**)

LEAD, CHLOROPHOSPHITE OF. Lead-salts added to a solution of alkaline phosphite, obtained by dissolving trichloride of phosphorus in water, and neutralising with an alkali, throw down a precipitate containing a compound of chloride and phosphite of lead, from which boiling water extracts the former.

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LEAD, DETECTION AND ESTIMATION OF. I. *Reaction*
dry way.—Lead-salts heated on charcoal with carbonate of sodium or cyanid
sium, give, in the inner blowpipe flame, bluish-white, malleable beads of me
surrounded by an incrustation of oxide, brownish-yellow while hot, but lig
yellow on cooling. Added, in rather large quantity, to a bead of microcosmic
give on cooling, a bead having an enamel-white colour, or yellow if quite sat

II. *Reactions in Solutions.*

Soluble lead-salts are colourless; the metal is precipitated from their sol
zinc or *iron*.

Sulphydric acid and *alkaline sulphides* throw down sulphide of lead as a
brownish-black precipitate, insoluble in cold and dilute solutions of acids, a
alkaline sulphides. In extremely dilute solutions, only a brown colouring is
If the solution of the lead-salt contains free hydrochloric acid, the precipitat
yellow, and a large excess of hydrochloric acid prevents it altogether.

Hydrochloric acid, added to solutions not too dilute, throws down chloride
white precipitate, slightly soluble in cold water, but more so in boiling water,
in needles on cooling; less soluble in dilute hydrochloric acid than in water,
freely in the strong acid; apparently unaffected by ammonia, but rendered i
water, from conversion into oxychloride.

Sulphuric acid and *soluble sulphates* throw down sulphate of lead as a
cipitate, scarcely soluble in cold water, ($\frac{1}{22,800}$ Fresenius), and in dilute sulp
($\frac{1}{36,500}$ Fresenius), almost absolutely insoluble in alcohol; soluble in stro
chloric acid on heating; in nitric acid more readily when strong and hot;
trated sulphuric acid, slightly; in ammoniacal salts, more especially the acet

Caustic potash or *soda* throws down the hydrate of lead as a white p
soluble in acids, or in excess of the reagent.

Ammonia throws down a white precipitate of basic lead-salt, insoluble in

Chromate of potassium throws down chromate of lead as a yellow preci
soluble in water (slightly soluble in excess, according to Conybeare), soluble
insoluble in dilute nitric acid, converted by ammonia into a red basic chrom

Iodide of potassium produces a bright yellow precipitate of iodide of l
dissolves in *boiling* water, and separates on cooling in crystalline spangles, e
beautiful play of colours.

LIMITS OF REACTIONS OF TESTS FOR LEAD.

One part of	In water,	Reagent.	Auth
Lead . . .	100,000 or more.	Sulphydric acid.	A. S.
Lead, as nitrate .	200,000	„	Lassa
Oxide of lead, as do. .	350,000	„	Har
Nitrate of lead .	100,000	„	Pfa
Oxide, as nitrate .	20,000	Sulphuric acid in exc.	Pfaff and
Lead, „ .	25,000	Sulphate of sodium (in 15 minutes).	Lassa
Oxide, „ .	70,000	Chromate of potassium.	Har

The reactions with sulphydric, sulphuric and hydrochloric acids, taken
serve to distinguish lead from all other metals. The reactions with iodide and
of potassium are also very characteristic.

III. *Quantitative Estimation.*

1. *Gravimetric methods.*—Lead is generally most conveniently est
sulphate. The concentrated solution is mixed with a slight excess of *dilute sulp*
and about twice its volume of alcohol, filtered after a few hours, the precip
washed with alcohol, and dried, and the filter burnt off. Or, a considerable
sulphuric acid may be substituted for the alcohol, in which case the wash-w
be also acidulated with sulphuric acid, and the last washings displaced by a
burning off, as much of the precipitate as possible is to be detached from
which should be burnt separately, to guard against reduction of lead. In a
is safest to employ a porcelain crucible.

2. Lead may also be weighed as oxide, into which it may be converted d
ignition, or after previous precipitation as oxalate or carbonate (results lo
chromate on a tared filter.

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Volumetric methods.—Many methods have been proposed for the volumetric estimation of lead, but the greater number give only approximate results. 1. Flores Domonte adds to the lead-solution a quantity of caustic potash or soda sufficient to redissolve the lead-oxide at first precipitated, and then adds to the boiling liquid from a burette, a graduated solution of *sulphide of sodium* as long as a precipitate is thereby produced. The greater part of the sulphide of lead cakes together, but the liquid remains brownish, so that it is difficult to see when the precipitation is complete. The method is, however, useful for technical purposes. The strength of the solution of sulphide of sodium must be determined every two days.

2. Margueritte adds to an alkaline lead-solution, a graduated solution of *permanganate of potassium*, which throws down the peroxides of lead and manganese, continuing the addition till the liquid exhibits a permanent green colour. The solution bumps very strongly when boiled, and the ready alterability of the solution of the permanganate necessitates frequent titration.

3. Pappenheim, according to Mohr, adds to the lead-solution a graduated solution of *sulphate of potassium*, till the liquid no longer produces a yellow spot of iodide of lead on paper prepared with solution of iodide of potassium. This method yields nearly exact results.

4. Streng (Ann. Ch. Pharm. xcii. 413) supersaturates a solution of a lead-salt, or sulphate of lead suspended in water, with potash; adds an excess of solution of *chloride of lime*, and boils for a while, whereby the lead is entirely converted into peroxide. The precipitate is collected on a filter and washed with hot water; a hole is then made in the bottom of the filter, and the precipitate washed through into the vessel in which it was formed; solution of *stannous chloride* is passed through the filter from a burette till all the peroxide of lead is washed off; the filter is again washed with hot water; and an excess of the tin-solution is added, whereby the peroxide of lead is converted into chloride, which is then dissolved by heating it with water and hydrochloric acid. If the excess of *stannous chloride* in the liquid be then determined by means of a standard solution of chromate of potassium, the whole of the data for calculating the amount of lead present in the liquid under examination will be obtained. This method is exact and often convenient.

5. The following process, given by Hempel (Jahresber. 1853, p. 627), is, however, simpler, and has the advantage of admitting of a double verification. The lead is precipitated with a measured quantity of a graduated solution of *oxalic acid* added in excess; the liquid is neutralised with ammonia, and the precipitate collected on a filter; the amount of oxalic acid in the filtrate is then determined by means of a standard solution of *permanganate of potassium*, and by deducting this amount from the total quantity of oxalic acid used, the quantity of oxalic acid combined with the lead is found, and thence the amount of the lead may be calculated.

The result may be checked, either by digesting the precipitate in dilute sulphuric acid, which sets the oxalic acid free, and estimating the amount of oxalic acid in the filtrate with a solution of permanganate — or by igniting and weighing the precipitate.

Mohr completes the determination without filtration. He adds to the solution, in a flask holding 300 cubic centimetres, a drop of tincture of litmus; then adds, from a burette, a standard solution of oxalic acid as long as a white precipitate is formed; saturates with ammonia till the liquid turns blue; fills the flask with water; leaves the liquid to stand for about half an hour till it is sufficiently clarified to allow of 100 cubic centimetres being removed clear with the pipette; and determines the free oxalic acid therein by means of a solution of permanganate, the quantity of which, multiplied by 3, gives the data required for determining the quantity of oxalic acid added in excess. It appears, however, that a small quantity of nitrate of lead is always precipitated together with the oxalate, so that the quantity of oxalic acid used always appears too small. Mohr estimates the errors thence arising at 2 per cent. (Handw. d. Chem. 2te Aufl. ii. [2] 33). On the whole, the volumetric methods of estimating lead do not appear to be so advantageous as the gravimetric methods.

IV. *Separation of Lead from other Metals*

From all metals, not precipitable as sulphides in acid-solution, lead may be separated, by passing *sulphydric acid gas* to saturation through the solution, previously made moderately acid with hydrochloric or nitric acid. The solution should also be moderately dilute. If no other metal, precipitable by the gas, be present, the precipitate will be sulphide of lead with an uncertain quantity of sulphur. If this is deflagrated with nitre, and the sulphur estimated as sulphate of barium, the difference between its weight and that of the precipitate, thoroughly dried at 100°, will give the lead. Or, by oxidising the precipitate in a porcelain vessel with fuming nitric acid, after detaching

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it as much as possible from the filter, burning the filter, and adding the ash, v
a mixture of sulphate of lead with a little nitrate. This may be converted into
by a slight excess of pure concentrated sulphuric acid; the precipitate is the
and weighed, and the lead calculated therefrom.

Of the metals precipitable by sulphydric acid, gold, platinum, arsenic, antimony may be further separated by digestion of the mixed sulphides in of ammonium containing an excess of sulphur. If, after this treatment, any mercury, bismuth, cadmium, or copper be left with the lead-sulph may be separated by one of the two following methods:—

If no bismuth is present, the solution containing the mixed oxides, is tre *carbonate of sodium*, and then digested with *cyanide of potassium*, when, on carbonate of lead will remain alone on the filter.

From bismuth, the lead may be separated by the following method, a also to its isolation from mercury, copper, and cadmium, but not from present in any quantity:—Evaporate with excess of sulphuric acid until fume appear, cool, and dilute with water; filter at once from the sulphate of lead; v acidulated water and alcohol; then dry and weigh.

The method of precipitation by sulphuric acid, or a soluble sulphate, serve to separate lead in solution without any preliminary treatment, from all m cepting barium, strontium, and calcium (and perhaps silver, *vid. sup.*), and fi earth-metals it is easily separated by sulphydric acid.

In alloys, lead may be very conveniently separated from bismuth, tin, and a and with rather more difficulty from arsenic, by converting all the metals into s and heating the sulphides in a stream of dry *chlorine gas;* all the other m then be volatilised, the lead alone remaining.

V. *Valuation of Lead Ores.*

a. By the wet way.—A very convenient process for determining lead in pecially in galena, consists in oxidising them with fuming nitric acid, adding acid in considerable excess to the slightly diluted solution, filtering and wa residue, as before directed, and after weighing, boiling it repeatedly with solution of acetate of ammonium, which dissolves the lead-sulphate. The residue deducted from the first weight gives the amount of lead-sulphate, fr the lead may be calculated.

b. By the dry way.—For the purposes of assaying, lead ores may be div two principal classes:—

A. Ores &c. which contain no sulphur, arsenic, or phosphorus.
B. Ores containing one or more of the above elements.

A. *First class.*—In the assay of these ores, two points require attention with a reducing agent for the separation of the lead, and with an alkali facilitate the formation of a clean button. Charcoal and argol are among reducing agents; carbonate of sodium, borax. deprived of its water by previo and salt, are useful as fluxes. Black flux, or a mixture of carbon in a fi division with carbonate of potassium, may also be employed. The following will give some idea of the proportions in which these reagents should be but they must, of course, vary somewhat for different ores:

	Sample.	Argol.	Charcoal.	Carbonate of sodium.	Borax glass.	S
No. 1.	200 gr.	100	. .	300	. .	200–2
2.	400 „	200	. .	400	200	
3.	400 „	200	. .	400	200	
4.	400 „	. .	50–60	600	. .	
5.	400 „	200	. .	400	. .	
6.	400 „	600	black flux, and a cover of borax			

1. Recommended by Mitchell for oxides, carbonates, cupel-products, &c.
2. „ „ cupel-bottoms and other refractory prod
3. „ „ fumes, siliceous slags, &c.

4, 5, 6. Phillips:—The salt is not mixed with the other reagents, but to cover the whole mixture.

Ores of this class may also be assayed by the following process, propos writer:—Weigh out 50 grs. of ore on a counterpoise. Fuse, at a red heat, ounce of crude cyanide of potassium in a crucible capable of holding at le the quantity; when fused remove it from the furnace, and add the ore in smal

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with a spatula; rinse the last traces off with a little more cyanide, and replace it for a minute or two in the fire, then take out the crucible, and tap to collect the lead into a button.

B. *Second class.*—Galena, pure, and mixed with gangue, is included in this class, for the assay of which several methods, more or less accurate, are employed, as—

1. *Roasting the galena*, by which it is converted into oxide, and treating the product as an ore of the first class. This process, besides being exceedingly troublesome, gives little more than three-fourths of the lead actually present.

2. *Fusion with* 3–4 *parts of alkaline carbonate;* the mixture to be heated slowly till fused, which gives about 90 per cent. of the lead present.

3. *Fusion with carbonate of sodium and nitre*, by which the sulphur of the ore is removed as sulphate of potassium; if an excess of the nitrate is employed, a portion of the lead is oxidised and lost. Several assays must therefore be made to discover the best proportions. This process answers very well for obtaining a button to be afterwards assayed for silver, in which case a slight excess of nitre must be used to ensure complete oxidation of the sulphur, without which some silver is liable to be retained as sulphide in the slag.

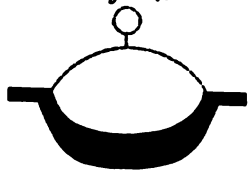
4. *Fusion with metallic iron*, which has been variously modified as to details. The oldest plan is that given by Berthier, in which the galena is simply mixed with about 30 per cent. of finely divided iron, covered with a layer of some flux and heated; it gives an amount of metal 7–10 per cent. below that actually present. Small iron nails are also recommended by Berthier, which is not a satisfactory process, as the nails become fixed in the button. Mitchell suggests the use of tenpenny nails; Phillips, of iron crucibles, and lastly, a mixture of iron-oxide with a reducing flux. Of these different modifications, the process of Mitchell is especially useful on account its simplicity and accuracy. We extract Mr. Mitchell's own description in full:

"To 200 grains of finely pulverised galena add 50 of argol, and 200 carbonate of soda; place the mixture in a crucible, the inside of which has been smeared with black-lead; introduce three tenpenny nails head downwards; tap the crucible on the mixing bench, so that the contents may occupy as little space as may be; cover with about 200 grains of salt, over that 200 grains of borax. Prepare two crucibles thus, place them in the furnace, and raise the heat rapidly to nearly a bright red; uncover the furnace, and allow the crucibles to remain for 8–10 minutes; again cover the furnace and raise to a bright red: the crucibles will then be ready for removal. Besides the time occupied, the termination of the assay may be judged by the flux flowing smoothly. When this occurs, seize hold of the crucible with the large tongs, and with a smaller pair take hold of one of the nails; rinse it well in the flux to remove any small globules of lead; and then reject it. The two other nails are to be treated in the same way, the crucible removed, tapped on the furnace top to collect all globules, and set aside to cool. So also with the second crucible. When cold they are broken, &c., as usual; the assays should correspond within one-eighth of a grain."

The following is an account of the process employed in the lead-works of North and South Wales, as an example of the rougher methods often adopted in smelting works with good practical results.

In the Welsh lead-works, the assays are generally made on 10 ounces of the ore as received, wet or dry. This is melted in a stout iron dish (*fig.* 637) with a cover, in a smithy fire; when melted, the slag is skimmed back and the produce weighed, each ounce representing 10 per cent., and each dwt. ¼ per cent. In the assay of galenas, some modification may be required; according to Mitchell, by fusing antimonial galenas with carbonate of sodium, pure lead is obtained, but with black flux, the lead contains much antimony; and if iron, either alone or mixed with black flux, be employed, all the antimony is obtained with the lead; but repeated tentative assays must be made to obtain the best possible result. When a lead ore contains oxidised compounds of sulphur and arsenic, reducers alone will not answer; but if they are mixed with an alkaline carbonate and metallic iron, good results are obtained. The assay may be conducted as in Mitchell's process for galenas.

Fig. 637.



A notable loss of lead is sustained in all the above processes, arising chiefly from the volatility of this metal and its oxide: hence the necessity of making all lead-assays at the lowest temperature compatible with perfect fusion, and of not keeping the assay in the furnace longer than is actually necessary. An error in the opposite direction may arise from the presence of foreign metals in the ore, which are more or less completely reduced and alloyed with the lead, increasing its weight; such, for example, as silver, copper, tin, or antimony. Zinc is completely removed if the heat

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be sufficient, but it entails a loss of lead. Iron does not go down with the
the assay be much overheated. The separation of most of these metals fr
the dry way, is impracticable, with the exception of silver in argentiferous
will bed escribed under *Cupellation* (see below).

Whatever process is employed to determine the lead, some standard is
the manufacturer, to which to refer in calculating the value of the ores. F
in Wales the "standard" is 77 per cent. or 7 oz. 14 dwts. on the assay. T
this standard fluctuates with the market price of lead, and for every variati
or half a per cent. an established addition or deduction is made in the p
silver present is calculated in ounces on the ton, and paid for per ounce.

The following tables have been constructed to save trouble in calculating
of assays:—

Produce of Lead per ton of Ore, calculated from Assay.

Per cent.	cwt.	qrs.	lbs.	Per cent.	cwt.	qrs.	lbs.	Per cent	cwt.
½	0	0	11	6	1	0	22	30	6
1	0	0	22	7	1	1	16	40	8
2	0	1	16	8	1	2	11	50	10
3	0	2	11	9	1	3	5	60	12
4	0	3	5	10	2	0	0	70	14
5	1	0	0	20	4	0	0	80	16

Produce of Lead per bing of Ore, calculated from Assay.

Per cent.	cwt.	qrs.	lbs.	Per cent.	cwt.	qrs.	lbs.	Per cent.	cwt	q
·10	0	0	·896	1·00	0	0	8·96	10·00	0	3
·20	0	0	1·792	2·00	0	0	17·92	20·00	1	2
·30	0	0	2·688	3·00	0	0	26·88	30·00	2	1
·40	0	0	3·584	4·00	0	1	7·84	40·00	3	0
·50	0	0	4·480	5·00	0	1	16·80	50·00	4	0
·60	0	0	5·376	6·00	0	1	25·76	60·00	4	3
·70	0	0	6·272	7·00	0	2	26·72	70·00	5	2
·80	0	0	7·168	8·00	0	2	15·68	80·00	6	1
·90	0	0	8·064	9·00	0	2	24·64			

Estimation of the Silver.—The separation of lead and silver in the dry w
process known as cupellation, depends on the fact, that while lead, when
the air at temperatures above its melting point, is rapidly oxidised, silver rem
tered. If, therefore, an argentiferous lead is heated in a current of air, on a
such a texture that the litharge formed from the lead shall be absorbed
produced, the silver will be finally left in the form of a button. This suppo
the "cupel," a flat, slightly hollowed-out dish of pounded bone-ash, compr
mould into the proper form. The process is conducted in a furnace, such as i
figs. 638, 639, where *a* is the ash-pit door; *d'* and *f*, doors for supply of fuel; *d*
ing by which access is obtained and the supply of air regulated to the muffl
muffle is a small fire-clay oven, situated in the centre of the fire, and pierced by
sides and inner end, which, when the door is opened, establish a current of a
the apparatus, while it is maintained at any desired temperature by means of
In using the apparatus, the muffle is first raised to a red heat; 4 to 8, or more,
cupels are then introduced, and the door closed. When they have attain
red heat, the door is opened, a button of lead is placed in each cupel by tong
door again closed. On opening it partially, the buttons are seen "uncovere
senting a bright metallic surface, and a dark ring instantly begins to form
circumference of the lead, as the litharge formed by its oxidation is absorb
cupel, the rings gradually extending as the buttons diminish. The moment
oxidation is completed and pure silver left, is recognised by a peculiar ph
known as the "brightening" of the silver button, which appears, for a
to revolve rapidly on its axis, while covered with a play of prismatic colo
play of colours disappears, and the button becomes still and lustrous.
withdrawn from the furnace, detached from the cupel, cleaned, and wei
balance turning with ·001 gr. Simple as the process appears, some
required, and many points demand attention, before uniform results can be

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The temperature should be the lowest at which the assay will proceed steadily, as a sensible amount of silver is volatilised with the vapour of lead. The temperature, on the other hand, must not be reduced *too* low, as the absorption of the litharge by the cupel is then impeded. Again, the draught, if too rapid, cools the cupel unduly, and if too slow, does not effect the oxidation with sufficient rapidity, thereby increasing the loss by volatilisation. Further, the absolute quantity of silver remaining the same, if the quantity of lead be much increased, the loss in silver will be greater. But, if the silver-lead be very rich, a loss will arise from the absorption of the alloy into the pores of the cupel. When the heat is too great, the cupels are whitish and the metallic matter they contain can scarcely be seen; the fume is scarcely visible, and rises rapidly

Fig. 638.

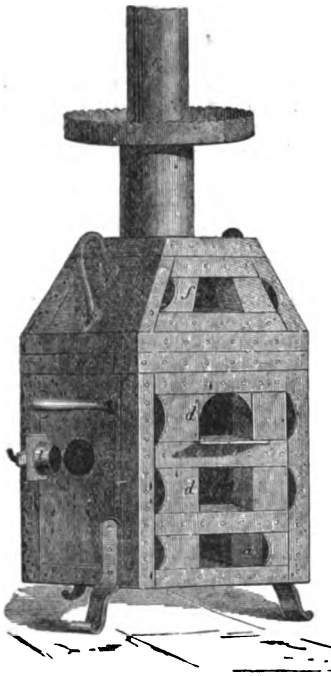
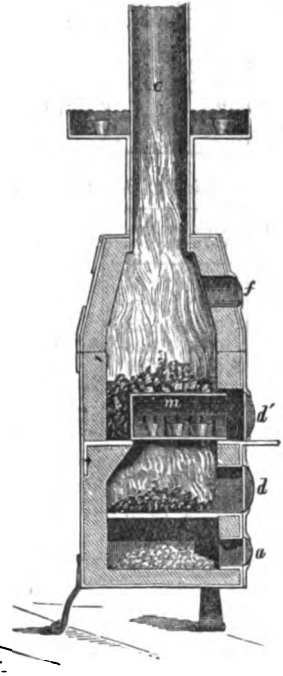


Fig. 639.



to the arch of the muffle. When the heat is not strong enough, the smoke is thick and heavy, falling in the muffle, and the litharge can be seen forming lumps and scales about the assay. When the heat is properly managed, the cupel is red, and the fused metal luminous and clear.

Lastly, a source of loss arises from what is termed "vegetation" of the button, which is due to the absorption of oxygen by the molten metal. When the metal is cooling, in a button of any size, the surface cools and solidifies before the centre has abandoned its mechanically dissolved gas, which, when it is liberated, forces its way through the external crust, raising it into fantastic arborescent forms, which, once seen, sufficiently explain the term. But as portions are frequently projected outwards by the sudden action, it is necessary to cover the cupel, while still hot, with a previously heated old cupel to secure its very gradual cooling. It is only, however, in the case of buttons much larger than a pin's head that this precaution is essential. The weight of the cupel ought to be about one-third greater than that of the lead to be cupelled; a good cupel will absorb its own weight of litharge under ordinary circumstances.

Lead is not the only metal which may be separated from silver by this process. Bismuth may be perfectly "cupelled," and copper, antimony, iron, tin, &c., may be "passed" by the addition of sufficient lead to carry their oxides into the cupel.

The following tables are useful in an assay office, where numerous assays are made from time to time, and they are constructed for different weights of lead cupelled, as well as the produce per 20 cwt. or ton and per 21 cwt. or fodder of lead:—

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Yield of Silver per ton, calculated from Assay of 400 grs.

400 grs. give	Yield per ton. oz. dwts. grs.	400 grs. give	Yield per ton. oz. dwts. grs.	400 grs. give	Yield pe oz. dwt
0·001	0 1 15	0·05	4 1 16	0·8	65
·002	0 3 6	·06	4 18 0	0·9	73 1
·003	0 4 21	·07	5 14 8	1·0	81 1
·004	0 6 12	·08	6 10 16	2·0	163
·005	0 8 4	·09	7 7 0	3·0	245
·006	0 9 19	·10	8 3 8	4·0	326 1
·007	0 11 10	·20	16 6 16	5·0	408
·008	0 13 1	·30	24 10 0	6·0	490
·009	0 14 16	·40	32 13 8	7·0	571 1
·010	0 16 8	·50	40 16 16	8·0	653
·020	1 12 16	·60	49 0 0	9·0	735
·030	2 9 0	·70	57 3 8	10·0	816 1
·040	3 5 8				

Yield of Silver per ton, calculated from Assay of 1 oz.

1 oz. gives grs.	Yield per ton. oz. dwts. grs.	1 oz. gives grs.	Yield per ton. oz. dwts. grs.	1 oz. gives grs.	Yield pe oz. dwt
0·001	0 1 11·84	0·05	3 14 16·0	0·8	59 14
·002	0 2 23·68	·06	4 9 14·4	0·9	67 4
·003	0 4 11·52	·07	5 4 12·8	1·0	74 13
·004	0 5 23·36	·08	5 19 11·2	2·0	149 6
·005	0 7 11·20	·09	6 14 9·6	3·0	224 0
·006	0 8 23·04	·10	7 9 8·0	4·0	298 13
·007	0 10 10·88	·20	14 18 16·0	5·0	373 6
·008	0 11 22·72	·30	22 8 0·0	6·0	448 0
·009	0 13 10·56	·40	29 17 8·0	7·0	522 13
·010	0 14 22·40	·50	37 6 16·0	8·0	597 6
·020	1 9 20·80	·60	44 16 0·0	9·0	672 0
·030	2 4 19·20	·70	52 5 8·0	10·0	746 13
·040	2 19 17·60				

Table of Silver per Fodder of Lead, calculated from Assay of 1 oz.

1 oz. gives grs.	oz. dwts. grs.	1 oz. gives grs.	oz. dwts. grs.	1 oz. gives grs.	oz. dwts
0·001	0 1 13·6	0·009	0 14 2	0·08	6 5
·002	0 3 3·2	·010	0 15 16	·09	7 1
·003	0 4 16·0	·020	1 11 8	·10	7 16
·004	0 6 6·0	·030	2 7 0	·20	15 13
·005	0 7 20·0	·040	3 2 17	·30	23 10
·006	0 9 9·0	·050	3 18 9	·40	31 7
·007	0 10 23·0	·060	4 14 1	·50	39 4
·008	0 12 13·0	·070	5 9 8		

VI. *Atomic Weight of Lead.*

The atomic weight of this metal has been determined chiefly by the experin
Berzelius, made in 1830 and 1845 (Pogg. Ann. xix. 300; *Lehrbuch*, 5te Aufl. iii
By reducing pure protoxide of lead with hydrogen gas, he found that 100 pts
protoxide contain 7·1724 pts. oxygen, whence, regarding the protoxide as Pb
putting oxygen = 16, the atomic weight of lead is 103·54; if, however, a certain
of the determinations, which do not agree very well with the rest, be left out of a
the atomic weight is found to be 103·57. The extreme limits of the determi
in question were 103·36 and 103·65. Within the same limits also are compri
older determinations of Berzelius (1818), which gave 103·56; also those of T
in 1835 (Ann. Ch. Pharm. xiii. 14), which gave 103·61, and nearly also t
Longchamp in 1827 (Ann. Ch. Phys. [2] xxxiv. 105), which gave numbers
from 103·64 to 103·74. The mean of all the best determinations is 103·56; or

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be regarded as diatomic, and the protoxide be represented by the formula $Pb''O$, then the atomic weight is 207·12. T. R.

LEAD, FLUORIDE OF, PbF^2, is obtained by precipitating acetate of lead with hydrofluoric acid, or by decomposing carbonate of lead with the same acid, as a white powder, sparingly soluble in water, easily fusible, soluble in hydrochloric and in nitric acid, by which it is decomposed on evaporation. When treated with aqueous ammonia or fused with oxide of lead, it is converted into a more soluble **oxyfluoride**, the solution of which has an astringent taste, and on standing in the air, deposits carbonate of lead, mixed or combined with fluoride of lead.

A **chlorofluoride** of lead has been already described (p. 539).

LEAD, HYDROALUMINOUS. See PLUMBORESINITE.

LEAD, IODIDE OF, PbI^2, is obtained by precipitating nitrate of lead with iodide of potassium, avoiding an excess of either salt. It is a precipitate of a fine light yellow colour; soluble in 1,235 pts. of cold water (Denort), and in 194 pts. of boiling water, forming a colourless solution, whence it crystallises on cooling in flexible, six-sided, laminar crystals. It is obtained in the same form by mixing the solutions of iodide of lead and iodide of potassium at the boiling heat. It is not more soluble in water containing acetic acid than in pure water. According to Henry, it is not quite insoluble in alcohol. Ether, according to A. Vogel, extracts iodine from it, leaving oxyiodide of lead. It dissolves in cold, and still more in warm aqueous sal-ammoniac, and crystallises therefrom on cooling in yellowish white needles (Boullay). In caustic ammonia, nitrate, succinate, carbonate, and sulphate of ammonium, it turns white (Wittstein). When boiled with the carbonates of the alkalis or alkaline earths, it yields carbonate of lead and a soluble iodide.

Iodide of lead, when heated, turns reddish-yellow and brick-red, then red-brown, and melts to a liquid of the same colour, which solidifies to a yellow mass. When fused in contact with the air, it gives off a part of its iodine, and leaves an oxyiodide of lead. It is easily decomposed by chlorine. Zinc or iron boiled with it under water takes up the iodine and precipitates metallic lead.

Iodide of Lead and Hydrogen, $PbI^2.2HI$, crystallises from a solution of iodide of lead in warm aqueous hydriodic acid, in concentrically grouped, silky needles, which give off the whole of the hydriodic acid when heated, and part of it even when exposed to the air at ordinary temperatures. The acid may also be extracted by water.

Ammonio-iodide of lead, or *iodide of plumbammonium*, $N^2H^6PbI^2$, is obtained as a white powder by passing ammonia-gas for a long time over finely-pulverised iodide of lead, or by digesting it at ordinary temperatures with sal-ammoniac. It gives off its ammonia spontaneously on exposure to the air, and even in an atmosphere of ammonia when heated.

Aceto-iodide of lead, $PbI.C^2H^3PbO^2$, or $\begin{matrix} C^2H^3O \\ Pb'' \end{matrix}\Big\}\begin{matrix} O \\ I \end{matrix}$, analogous to glycolic iodacetin (ii. 568), is obtained in a similar manner to the corresponding chlorine-compound (p. 539), with which it is isomorphous. (Carius, Ann. Ch. Pharm. cxxv. 87.)

An *iodochloride of lead*, $Pb^3Cl^4I^2$, has been already described (p. 539).

An *iodide of lead and ammonium* is formed, as a white precipitate, on adding iodide of ammonia in excess to nitrate of lead.

A compound of *iodide of lead* with *chloride of ammonium*, $3NH^4Cl.PbI^2$, is obtained by dropping a solution of neutral acetate of lead into a boiling mixed solution of iodide of potassium and sal-ammoniac, as long as no permanent precipitate is formed. On cooling, the double salt crystallises in slender yellow, shining needles, which, however, are decomposed by water, the sal-ammoniac dissolving out first.

Another compound, $2NH^4Cl.PbI^2.2H^2O$, crystallises in white silky needles.

Iodides of lead and potassium.—When 1 at. iodide of lead (PbI^2) and 1 at. iodide of potassium are dissolved in the smallest possible quantity of boiling water, the solution yields on cooling, large yellow, shining, six-sided laminæ, having the composition $KI.PbI^2$, and on dissolving these crystals in a hot solution of iodide of potassium, white silky needles, consisting of $4KI.PbI^2$, are deposited as the liquid cools. Both salts are decomposed by water and by alcohol.

LEAD ORES. The following is a list of minerals containing lead as an essential constituent, and available, when they occur in sufficient quantity, for the extraction of the metal:

Aciculite. Aikinite. Belonite. Needle-ore.

Patrinite. $\begin{matrix} \dot{Pb}^2 \\ (Cu^2)'' \end{matrix}\Big\}S^3.Bi^2S^3$.

Altaite. Telluride of lead. PbTe.

Aluminate of lead (hydrated). Plumboresinite. $\begin{matrix} \dot{Pb} \\ \dot{Al}^4 \end{matrix}\Big\}O^7.6H^2O$.

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Anglesite. Sulphate of lead. Lead-vitriol. $PbSO^4$.

Antimonial sulphides of lead: see Boulangerite, Bournonite, Brogniardite, Freislebenite, Geocronite, Heteromorphite, Jamesonite, Kobellite, Plagionite, Zinkenite.

Antimonate of lead. Bleinierite. $Pb^3Sb^2O^8.4H^2O$.

Arœoxene. Zinkiferous vanadate of lead.

Arsenate of lead: see Mimetite.

Arsenomelane. $2PbS.As^2S^3$.

Binnite. A mixture of Arsenomelane and Scleroclase.

Bleinierite. Antimonate of lead.

Boulangerite. $3PbS.Sb^2S^3$.

Bournonite (to which is related Wölchite).

$$(2PbS.Cu^2S).Sb^2S^3 = \left.\begin{matrix} \overset{\cdot\cdot}{Pb}^2 \\ (Cu^2)'' \\ \overset{\cdot\cdot}{Sb}^2 \end{matrix}\right\} S^6.$$

Brogniardite. $PbAg^2S^2.Sb^2S^3$.

Caledonite. $(Pb;Cu)CO^3.PbSO^4$.

Carbonate of lead. Cerusite. White lead ore. $PbCO^3$.

Cerasin. Corneous lead. Horn-lead. Chlorocarbonate of lead. Phosgenite. $PbCl^2.PbCO^3$.

Cerusite: see Carbonate of lead.

Chileïte. Vanadate of lead and copper. $(Pb;Cu)^3(VO^4)^2.3(Pb;Cu)O$.

Chiviatite. $2PbS.3Bi^2S^3$.

Chloride of lead. Cotunnite. $PbCl^2$.

Chlorarsenate of lead: see Mimetite.

Chlorocarbonate of lead: see Cerasin.

Chlorophosphate of lead: see Pyromorphite.

Chromate of lead: see Crocoïsite, Melanochroïte, Red lead ore, Vauquelinite.

Clausthalite. Selenide of lead. PbSe.

Corneous lead. Syn. with Cerasin.

Cotunnite: see Chloride of lead.

Crocoïsite. Chromate of lead. $PbO.CrO^3 = \left.\begin{matrix} Pb'' \\ Cr^{vi} \end{matrix}\right\} O^4$.

Cupreous sulphate of lead: see Linarite.

Cupreous sulphatocarbonate of lead: see Caledonite.

Cuproplumbite. $2PbS.CuS$.

Dechenite. Vanadate of lead. PbV^2O^6.

Descloïzite. $Pb^2V^2O^7$ or $2PbO.V^2O^5$.

Embrothite: see Boulangerite.

Eusynchite. Syn. with Dechenite.

Freislebenite. $Pb^3Ag^4S^5.2Sb^2S^3$.

Galena. Lead-glance. Sulphide of lead. PbS.

Geocronite. Arseniferous Schulzite.

Heteromorphite. Feather-ore. Plumosite. $2PbS.Sb^2S^3$.

Hydroaluminous lead: see Aluminate of lead.

Kilbrickenite. $6PbS.Sb^2S^3$.

Kobellite. $\left.\begin{matrix} \overset{\cdot\cdot}{Pb}^3 \\ (\frac{2}{3}\overset{\cdot\cdot\cdot}{Sb}.\frac{1}{3}\overset{\cdot\cdot\cdot}{Bi})^2 \end{matrix}\right\} S^6$.

Lanarkite. Sulphatocarbonate of lead. $PbCO^3.PbSO^4$.

Lead-glance: see Galena.

Lead, native.

Lead ochre. Native protoxide of

Lead ore, green: see Mimetite a morphite.

Lead ore, red: see Minium.

Lead ore, white: see Cerusite.

Lead ore, yellow: see Molybdate

Leadhillite. Sulphatotricarbonat $3PbCO^3.PbSO^4$.

Lehrbachite. Selenide of lead a cury. (Pb;Hg)Se.

Linarite. Cupreous Anglesite. sulphate of lead. $CuH^2O^2.PbS$

Matlockite. Pb^2Cl^2O.

Melanochroïte. Phœnicite. chroïte. $3PbO.2CrO^3 = \overset{\cdot\cdot}{Pb}_{(Cr^{vi}}$

Mendipite. $Pb^3Cl^2O^2$.

Meneghinite. $4PbS.Sb^2S^3$.

Mimetite, Mimetesite, Mimetene. lead ore. $PbCl^2.3Pb^3As^2O^8$. is related Hedyphane, contain calcium and phosphorus.

Minium. Red oxide of lead (p.

Molybdate of lead. Wulfenite. lead ore. $PbO.MoO^3 = \left.\begin{matrix} Mo^{vi} \\ Pb'' \end{matrix}\right\}$

Muriocarbonate of lead. Syn. rasin.

Nagyagite. Foliated Tellurium $Au^2).(Te;Se)$.

Needle ore: see Aciculite.

Oxides of lead: see Lead ochre, and Plattnerite.

Oxychloride of lead: see Matloc Mendipite.

Patrinite: see Aciculite.

Phœnicite or Phœnicochroïte: lanochroïte.

Phosgenite: see Cerasin.

Phosphate of lead: see Pyromorp

Plagionite. $4PbS.3Sb^2S^3$.

Plattnerite. Peroxide of lead. A doubtful species.

Plumboresinite: see Aluminate o

Plumbostib: see Boulangerite.

Polysphærite. Pyromorphite co calcium.

Polytelite. $4(Pb;Ag^2)S.Sb^2S^3$.

Pyromorphite. Green lead ore. phosphate of lead. $3Pb^3P^2O^8$ or PbF^2.

Schulzite. $5PbS.Sb^2S^3$.

Selenate of lead. $PbSeO^4$.

Selenide of lead: see Claustha Lehrbachite.

Stolzite: Tungstate of lead.

Sulphate of lead: see Anglesite.

Sulphatocarbonate of lead: see ite.

Sulphatotricarbonate of lead: s hillite, and Sulzannite.

Sulphide of lead: see Galena.

Sulzannite. Rhombohedral sul carbonate of lead. $PbSO^4.3Pb$

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Telluride of lead: see Altaïte, and Nagyagite.

Tungstate of lead: see Stolzite.

Vauquelinite. $3CuO, 6PbO\}4CrO^3$.

Vanadate of lead: see Dechenite, Descloïzite, and Vanadinite.

Vanadinite. $3Pb^3V^2O^8.PbCl^2$.

Wölchite: see Bournonite.

Wulfenite. Molybdate of lead.

White lead ore: see Cerusite.

Zinkenite. $PbS.Sb^2S^3 = \left.\begin{matrix}Pb\\Sb^2\end{matrix}\right\}S^4$.

The ores which are actually worked for lead have been already described (pp. 480, 481): for the rest, see the several articles.—Respecting the working of lead ores, see pp. 481—531; methods of assaying them, p. 543.

LEAD, OXIDES OF. Lead forms five oxides, viz.:

The Suboxide	Pb^2O.
The Protoxide	PbO.
The Red oxide	Pb^3O^4.
The Sesquioxide	Pb^2O^3.
The Dioxide or Peroxide	PbO^2.

The protoxide is a strong base; the sesquioxide and peroxide also unite with acids. The red oxide is decomposed by most acids. All the oxides of lead are easily reduced to the metallic state by charcoal at a red heat.

Suboxide. Pb^2O.—This oxide, which was discovered by Dulong, remains when oxalate of lead is cautiously heated in a retort from which the air is excluded. According to Pelouze (Ann. Ch. Pharm. xlii. 209), the retort should be heated in an oil-bath to a temperature not exceeding 300°, the heat being continued as long as any gas is given off: the gas thus evolved is a mixture of 1 vol. carbonic oxide and 3 vol. carbonic anhydride:

$$2PbC^2O^4 = Pb^2O + CO + 3CO^2.$$

The whole is suffered to cool before the suboxide is removed. It forms a black powder, sometimes dull, sometimes having a velvety lustre. It contains no metallic lead, for mercury extracts nothing from it, either dry or under water; neither does it contain any protoxide, for the aqueous solution of acetate of lead does not extract any protoxide from it on boiling. But when heated to dull redness, out of contact of air, it is resolved into a greenish-yellow mixture of lead and protoxide (Boussingault, Pelouze). After this treatment, mercury extracts lead from the substance, and a boiling solution of acetate of lead or acetic acid leaves the lead in the form of a network, which, when pressed together between the fingers, forms a dense mass having the metallic lustre. The suboxide heated in the air takes fire, burns with a glimmering light, and is converted into protoxide. Dilute *sulphuric, nitric, hydrochloric,* or *acetic acid* resolves it into protoxide, which combines with the acid, and very finely-divided metallic lead. The same effect is produced by a strong solution of *normal nitrate of lead*; a dilute solution, on the contrary, takes up the whole of the suboxide and forms basic nitrate of lead. The suboxide, when moistened with *water*, rapidly absorbs oxygen from the air, and is converted into the white hydrated protoxide, the action being attended with rise of temperature. A mixture of finely-divided lead and litharge does not yield the same result.

The grey pellicle which forms upon lead exposed to the air, has also, according to Berzelius, the composition Pb^2O.

Protoxide. *Lead-oxide.* PbO.—This oxide occurs native as lead-ochre, a massive mineral, sometimes with scaly crystalline structure. Specific gravity 8·0. Lustre dull. Opaque. Colour between sulphur- and orpiment-yellow. Streak lighter than the colour. It does not soil. It is said to occur at Badenweiler, in Baden, and, according to Gerolt, has been ejected from the volcanoes Popocatapetl and Iztaccituall, in Mexico. It is found also at other localities in Mexico, and at Austin's mines, Wythe county, Virginia. (Dana, ii. 109.)

Protoxide of lead is obtained pure by igniting the basic nitrate, or the carbonate or oxalate of lead, in a platinum crucible, in contact with the air, taking care that the oxide does not fuse, otherwise it will take up metal from the crucible, and if heated in a porcelain crucible, would take up silica. The pure oxide thus obtained has a lemon-yellow colour, and a specific gravity of 9·4214.

On the large scale, protoxide of lead is obtained in the forms of massicot and litharge.—1. *Massicot* is prepared by heating lead to low redness on a flat hearth, and continually removing the film of oxide as it forms, till the lead-ash at first obtained is, for the most part, converted into the yellow oxide; the latter is then freed from the still remaining metallic portions by grinding and levigation.—2. *Litharge* is obtained in the oxidation of *pig-lead* containing gold and silver—the resulting lead-oxide, which is

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generally contaminated with silica, ferric oxide, cupric and cuprous oxide, a oxide, and other oxides, is fused by the high temperature, and solidifies shining mass, sometimes of a yellowish tint (*Argyritis, Silber-glätte*), somet inclining to red (*Chrysitis, Goldglätte*). The oxide of copper may be removed by digesting the levigated litharge with aqueous solution of carbo monia (Bischof, Schw. J. 64, 65).—The antimonious oxide is left behind o the litharge in boiling nitric acid, and may then be dissolved in hydro (Anthon, Repert. 58, 387.)—The difference between red and yellow lithar buted by Leblanc (J. Pharm. [3], Sept. 8, 1845) to a mere diversity structure, not of chemical composition; for either modification may be o pleasure by properly regulating the temperature and the rate of coolin variety, which is specifically lighter than the yellow and more crystalline s formed most abundantly when the cooling is slow. (See also p. 514.)

Properties.—Protoxide of lead appears to be both dimorphous and occurring in pale-yellow rhombic octahedrons and cubes, and regular dod and as a red amorphous powder. By the following processes it may be obta crystalline state:—1. *By slow cooling after fusion.* Litharge, when qui solidifies in a mass of crystalline scales; but the portion which remains on sometimes crystallises in yellow, translucent, six-sided tables (Marx); octahedrons with a distinct plane of cleavage (Mitscherlich); in regu hedrons, the angles of which are indefinite, in consequence of the curva faces (Gaultier de Claubry and Beudant). White lead fused by th flame on a copper plate or other non-reducing support, crystallises in scales but from the middle of it there generally shoots out a mass, half a line long, in the form of a triangular pyramid, sometimes in that of a nearly perfe dodecahedron, of a hyacinth-red tint while hot, becoming sulphur-yellow lucent as it cools, and opaque and dull when perfectly cold. This alternate crystallisation may be repeated several times.—2. *By fusion with hydrate of* If 1 part of lead-oxide and from 4 to 6 of hydrate of potassium be fused time in a silver crucible at an incipient red heat, and the mass after cooling with water, the lead-oxide remains in the form of cubes and square tables (B Ann. Ch. Phys. [2], li. 105).—3. *By treating lead-oxide with potash or soda-* a solution of lead-oxide in soda-ley, saturated while hot, placed in a stopp and then left to itself all through the winter, the lead-oxide crystallises in s translucent rhombic dodecahedrons (Houton-Labillardière, J. Pharm The crystals are trimetric octahedrons, having the same angles as those o fusion (Mitscherlich). Strong boiling potash-ley saturated with lead-o on cooling, yellow scales similar to those of litharge; if the potash-solution saturated with lead-oxide, or if it has deposited the excess of that oxide i further deposition takes place till after perfect cooling, whereupon red scales down, perfectly soluble in acetic acid, and therefore free from minium; if thes heated, they turn yellow on cooling. Hence it appears that litharge may colour without containing minium or red oxide of copper (Mitscherlich, J xix. 451).—Boiling soda-ley of 40°—41° B., saturated with hydrate of l rose-red crystals of the protoxide on cooling. These crystals yield an ora powder, similar to that of litharge. At about 400° they turn black, incre decrepitate with loss of 0·1 per cent. of water—and when heated to lo assume a sulphur-yellow colour without changing their form. While still state, they dissolve, though very sparingly, in nitric acid, either concentrate (Calvert, Compt. rend. xvi. 136). If hydrated lead-oxide be boiled with of aqueous alkali not sufficient to dissolve it, the undissolved portion be verted into crystalline anhydrous oxide; the resulting solution, when evapor more crystals of the anhydrous oxide, distinguished from the former porti easy solubility in alkalis, even when dilute (Frémy, J. Pharm. [3], iii. 3 *precipitating a lead-salt with excess of alkali.* Solution of neutral acet mixed with excess of ammonia and exposed to the sun for a few days, y green, very hard crystals of anhydrous oxide (Tünnermann, Kastn. Arch. Behrens (J. Pharm. [3], iv. 4, 18) supersaturates the sugar-of-lead solut quantity of ammonia sufficient to re-dissolve the precipitate; filters to se carbonate of lead that may have been formed; puts the filtrate into a bottle; and exposes it to the rays of the sun. After a few hours, transpare make their appearance, colourless at first, but afterwards becoming yell finally yellowish-grey. Their powder is white, but assumes a dark brown after long trituration.—4 measures of solution of lead-acetate, saturated at with 100 measures of boiling water, and then with 45 measures of aqueous deposit, in the course of half a minute, a large number of very delicate, yello rhomboïdal laminæ, having a silvery lustre and united in tufts; these lami

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separated by levigation from the crystalline granules of hydrated oxide, which fall down at the same time, then washed with boiling water, and dried in vacuo. When ignited, they do not give off any water—or only a trace of it, with decrepitation—neither do they lose their transparency. They may be obtained without admixture of hydrate, by boiling 100 measures of a saturated solution of triplumbic acetate with 50 measures of water, adding thereto a mixture of 50 measures of water at 80°, and 8 measures of aqueous ammonia, and heating the mixture in the water-bath. In the course of a minute, crystals of the oxide separate, free from hydrate, the formation of the latter being prevented by the high temperature (Payen, Ann. Ch. Phys. [2], lxvi. 54).—*5. By placing lead in contact with air and water.* On the bottom of a leaden vessel filled with water, there are first formed a number of white flakes of hydrated basic carbonate of lead, then shining grey crystals of anhydrous oxide, partly in scales like mica, partly in rhombic dodecahedrons with cube-faces. When heated, they become opaque and orange-coloured, but without losing weight or lustre. (Yorke, Phil. Mag. [3] v. 82.)

The specific gravity of protoxide of lead is 9·20092 (Karsten), 9·277 (Herapath), 9·363 (Playfair and Joule); after fusion 9·50 (Boullay). According to Leblanc (Ann. Ch. Pharm. lvi. 235), the specific gravity of litharge is greater after slow than after quick solidification. The cubical expansion between 0° and 100° is 0·00795. At a red heat it melts to a clear dark red liquid, which solidifies to a reddish-yellow crystalline mass.

Protoxide of lead unites readily with *acids*, forming neutral and very soluble salts, and likewise exhibits a decided chlorous or negative reaction towards strong *bases*. It dissolves readily in caustic *potash* and *soda*. *Baryta*-water and *lime-water* also dissolve it, and the lime-compound is said to crystallise in sparingly soluble needles. By boiling the protoxide with milk of lime, a liquid is obtained which may be used for producing a black dye on hair, nails, horn, and wood.

An *oxide of lead and silver*, $Ag^2O.2PbO$ or $Ag^2Pb^2O^3$, is obtained by adding caustic potash to a solution of a lead-salt mixed with a silver-salt, as a yellow precipitate insoluble in excess of the alkali, and thereby easily separated from admixed lead-oxide. It is easily soluble in nitric acid; blackens on exposure to light; leaves, when ignited, a mixture of lead-oxide and metallic silver; and when quietly heated in hydrogen gas is reduced to an easily fusible alloy of the two metals. (Wöhler, Pogg. Ann. xli. 344.)

Protoxide of lead dissolves, according to Bineau, in 7,000 pts. of pure water, forming a solution which decomposes most salts of the alkali-metals. The solubility is greatly diminished by the presence of certain salts, *e.g.* sulphates, phosphates and carbonates, and increased by that of ammonia and its salts (p. 47).

Hydrate, or *Hydrated Oxide of Lead*, is obtained on adding a solution of neutral acetate of lead to excess of ammonia, as a white amorphous precipitate containing $3PbO.2H^2O$ (Payen), or $2PbO.H^2O$ (Schaffner), or, according to older statements, $PbO.H^2O$ or PbH^2O^2. If the solution be heated, the anhydrous protoxide is formed at the same time. When lead is immersed in pure water, hydrate of lead is formed, and partly dissolves (v. Bonsdorff). The hydrate precipitated on treating nitrate or acetate of lead with caustic potash is always mixed, according to Winkelblech, with a certain quantity of basic salt. According to other statements, however, the acid which it contains may be completely removed by digestion with a slight excess of alkali.

The hydrate prepared by precipitation with ammonia, as above, appears under the microscope to be composed of prismatic crystals. It must be protected from the air during washing, otherwise it will absorb carbonic acid. It retains its water at 100°, but gives it up at a somewhat higher temperature, and is converted into the anhydrous protoxide, which is red while hot, yellow after cooling.

Hydrate of lead takes up *ammonia*, forming the two compounds $2NH^3.PbO.H^2O$ and $2(NH^3.4PbO).H^2O$. (Calvert, Compt. rend. xxii. 480.)

Red Oxide of Lead. *Red Lead. Minium.* $Pb^3O^4 = 2PbO.PbO^2$ or $PbO.Pb^2O^3$.—This oxide is formed when the protoxide is kept at a low red heat for a considerable time in contact with the air; also, after previous formation of hydrated protoxide and basic carbonate of lead, when lead-shavings are strewn upon water, the vessel being loosely covered, and then set aside for some months, the formation of red lead taking place chiefly on those surfaces of the metal which are exposed to the air. In like manner, drawings made with lead turn red in the course of years. (v. Bonsdorff.)

The red oxide also occurs native in certain localities, mixed with other ores of lead, and probably resulting from their oxidation, viz. at Bleialf and Kall in the Eifel, at Badenweiler in Baden; at Brillon in Westphalia; on Grassington Moor, and in Weirdale, Yorkshire; in the Isle of Anglesey, and at Austin's Mine, Wythe County, Virginia, where it accompanies cerusite.

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Red lead is extensively used as a pigment, and in the manufacture of flint It is prepared on the large scale in this country, chiefly in Derbyshire, by ox lead in a reverberatory furnace having two *fire-hearths*, covered by an ellip arched roof; they are situated at the extreme end of the furnace, and are sep from the middle hearth, or *lead-hearth*, by low walls or fire-bridges. The fuel coke. About 1,500lbs. of lead (one-tenth consisting of hard lead) are placed up lead-hearth, and worked about, as soon as it is melted, with an iron crutch, the (massicot) as it forms being pushed to the side of the hearth. The tempe must not be raised above low redness, so that the oxide may not melt. A hours, the massicot is taken out, reduced, to very fine powder by grinding and tion, again placed upon the lead-hearth, and exposed to the same temperat before for 48 hours, or till a sample taken out appears dark red when hot, and red on cooling. The furnace must then be closed, and left to cool slowly, a co mainly essential to the success of the operation. In Germany the conversion massicot into red lead is effected in a peculiar furnace, in which the massicot is not on a hearth, but in barrel-shaped vessels open at both ends. Sometim operation is repeated in order to improve the colour. Carbonate of lead may used, instead of massicot, for conversion into red lead, but when the temperat properly regulated, another pigment is obtained, called *Orange Lead*. Red lea prepared, which, however, retains a little carbonic acid, is known as a pigment name of Paris red.

To free commercial red lead from the yellow oxide mixed with it, Dumas dig repeatedly with solution of lead-acetate; Berzelius and Dalton recommend tre with cold, very dilute acetic acid; Phillips recommends 144 pts. at most, of acetic acid diluted with a large quantity of water to 100 of minium, inasmuc more acid be used, the brown peroxide is likewise formed. According to I however, peroxide of lead is always formed in the purification of minium, bef whole of the free protoxide is extracted, even when the dilutest acetic acid is em

Commercial red lead likewise contains all the foreign metallic oxides—such oxides of copper, iron, and silver—with which the massicot or litharge used i paring it is contaminated. Red lead is likewise often adulterated with oxide o red bole or brick-dust; these substances remain undissolved when the red lead gested in warm dilute nitric acid; boiling hydrochloric acid extracts sesq of iron from the residue. When red lead thus adulterated is ignited, there re mixture of yellow lead-oxide and the red substances that have been added to it

On the small scale, red lead may be obtained of very fine colour by the fol processes:—1. When 4 pts. of lead-oxide, prepared by igniting white lead, are in a silver or platinum crucible with 1 pt. of chlorate of potassium and 8 pts. o (the latter acting as a flux and thereby saving the chlorate), brown peroxide of first obtained; but this, when further heated to dull redness, is converted, wit mescence and thickening of the mass, into red lead. As soon as the red lead to decompose at the edge of the crucible, the mass is suffered to cool, and the r well boiled with water containing potash.—2. By boiling peroxide of lead with a plumbate of potassium, or 1 pt. of the peroxide with 5 pts. of lead-nitrate quantity of aqueous potash or soda sufficient to redissolve the hydrate of lead fi cipitated, till a brown-red mixture of minium with a small quantity of the pero produced, and digesting this mixture, after washing, with oxalic acid, which poses the peroxide without acting on the minium. The minium obtained process is rather dark-coloured, but becomes brighter when rubbed up with wa has the same composition as that which is obtained by the ordinary method. (Ann. Ch. Phys. [3] lxxv. 108.)

Properties.—Red oxide of lead is a scarlet, crystalline-granular powder; heated, it first assumes a finer red colour, and then turns violet. Specific gravi (Karsten), 8·94 (Muschenbroek), 9·082 (Herapath); of native minium 4·6 (Dana, ii. 126.)

Red lead was formerly supposed, according to analyses by Richter, Wi Thomson, and Berzelius, to be a sesquioxide, Pb^2O^3; but it is probable t products examined by these chemists contained protoxide or carbonate of le Dumas has shown that the perfectly pure red oxide specially prepared for ana the commercial product freed from protoxide by digestion with solution of ac lead, contains 90·63 per cent. lead and 9·37 oxygen, numbers agreeing exactly v formula Pb^3O^4. It may be regarded either as a compound of the protoxide a oxide of lead, $2PbO.PbO^2$, or perhaps of the protoxide and sesquioxide, PbO analogous to magnetic oxide of iron. Jacquelain (J. pr. Chem. liii. 151) fou a mixture of 1 at. PbO and 1 at. PbO^2, heated to 450°, assumed a fine red gave off no oxygen, and was afterwards perfectly soluble in potash-ley and acetic acid. It is possible, however, that there may be more than one red o

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lead intermediate in composition between the proto- and peroxides; for a crystallised red lead from a minium furnace, analysed by Houton-Labillardière, exhibited the composition $3PbO.PbO^2$.

Decompositions.—1. By rather strong ignition, red lead is resolved into the protoxide and 2·4 per cent. of oxygen gas (Dumas).—2. By many oxidable bodies, at various temperatures, it is reduced to the protoxide. Aqueous *sulphurous* and *nitrous* acids, at ordinary temperatures, convert it respectively into sulphate and nitrate of lead; *sulphurous acid* acts very slowly in the cold, but rapidly on the application of heat. *Dichloride of tin* converts it, with a rise of temperature of 13°, into chloride of lead and stannic oxide (A. Vogel, Kastn. Arch. xxiii. 84). It is likewise reduced by boiling with a solution of *sugar*, and oxidises many organic acids. When 2 pts. of red lead and 1 pt. crystallised tartaric acid are rubbed up to a thin paste with a small quantity of water, the mixture becomes hot and whitish, and the odour of formic acid is given off (Böttger).—3. By a small quantity of *hydrochloric acid*, red lead is converted into chloride of lead, peroxide of lead, and water:

$$Pb^3O^4 + 4HCl = 2PbCl^2 + PbO^2 + 2H^2O.$$

By a larger quantity of hydrochloric acid, into chloride of lead, chlorine gas, and water:

$$Pb^3O^4 + 8HCl = 3PbCl^2 + Cl^2 + 4H^2O.$$

4. By *chlorine-water*, into chlorine and peroxide of lead:

$$Pb^3O^4 + Cl^2 = PbCl^2 + 2PbO^2.$$

Similarly with *bromine-water* (Löwig). Minium is not decomposed by mercurous nitrate or oxalic acid. (Levol.)

Heated with *strong sulphuric acid*, it yields sulphate of lead and free oxygen. By *nitric acid*, *dilute sulphuric acid*, and likewise by weaker acids, such as ordinary *acetic acid*, it is resolved into protoxide and peroxide, the former dissolving in the form of an ordinary lead-salt, while the latter remains undissolved. In *glacial acetic acid*, however, it dissolves completely; and when considerable quantities of it, but not quite sufficient for saturation, are dissolved in that acid at 40°, the liquid on cooling deposits prismatic crystals of acetate of peroxide of lead, while an acetate of the sesquioxide remains in solution (Jacquelain, J. pr. Chem. liii. 151). According to Schönbein (*ibid.* lxxxiv. 315), concentrated acetic acid shaken up for about 15 minutes with levigated minium, takes up about 9 per cent. of it, forming a solution which is quickly decomposed by heat or by dilution, but appears to be stable at −18°. Sulphuric acid added to this solution throws down all the protoxide of lead contained in it, leaving a pure solution of acetate of peroxide, which deposits the peroxide slowly at ordinary temperatures, quickly when warmed. Potash added to the solution of minium in acetic acid, throws down, not minium, but a mixture of the proto- and peroxides, which blues tincture of guaiacum and iodised starch-paste, reactions not produced by pure minium. The solution of minium, and that of the pure peroxide in acetic acid, immediately decolorise solution of indigo; when shaken up with finely divided zinc, iron, lead, copper, or even silver, they form acetates of these metals and lose their oxidising properties. The same solutions convert iodine into iodic acid, sulphurous acid into sulphuric acid, sulphide of lead into sulphate, and act strongly at common temperatures on oil of turpentine. (Schönbein.)

Minium likewise dissolves in cold concentrated aqueous *phosphoric* and *arsenic acids*, forming salts of the peroxide. (Jacquelain, see p. 555.)

Sesquioxide of Lead. Pb^2O^3.—Hypochlorite of sodium throws down from lead-salts, a reddish-yellow mixture of sesquioxide and chloride of lead, which, if warmed or left to stand for some time, turns brown from formation of peroxide. To obtain the sesquioxide free from chloride, nitrate of lead is supersaturated with potash in sufficient quantity to redissolve the precipitate, and then treated with hypochlorite of sodium. The yellow precipitate, when washed and dried, yields a soft, non-crystalline, reddish-yellow powder, which may be dried over oil of vitriol. At a red heat, the sesquioxide is resolved into 6·47 per cent. of oxygen gas, and 96·53 per cent. of protoxide. By oxalic acid and by formic acid it is reduced to protoxide, with evolution of heat. With nitric, sulphuric, hydrofluosilicic and acetic acids, generally without the application of heat, it is converted into peroxide and a salt of the protoxide. It dissolves in cold hydrochloric acid, forming a yellow liquid from which it is again precipitated by alkalis: the liquid, however, resolves itself in a few minutes into chloride of lead and free chlorine. (Winkelblech, Ann. Ch. Pharm. li. 176.)

The sesquioxide may also be obtained by precipitating a solution of the red oxide in acetic acid (*vid. sup.*) with caustic alkalis or alkaline carbonates. If the fixed alkalis are used, the sesquioxide always retains a portion of the precipitant, which cannot be removed by washing; but by pouring the acetic solution into very dilute ammonia,

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separating the precipitate quickly from the liquid, washing it with hot water c
a very small quantity of acetic acid, and drying at 100°, the sesquioxide is
pure, having the colour of ferric oxide, and differing in external appearance f
obtained by Winkelblech, but agreeing with it in composition and reactions
heated to 150°, it becomes darker, like ignited ferric oxide, but does not deco

The acetic solution of the sesquioxide may be mixed, without decomposit
from 4 to 6 times its volume of alcohol of 96° Tr. (Jacquelain, *loc. cit.*)

Dioxide or Peroxide of Lead. *Brown or puce Lead.* PbO^2.—Th
is obtained: 1. By exposing the protoxide suspended in water to a st
chlorine gas. Wöhler precipitates a solution of 4 pts. of acetate of lead wit
tion of 3 pts. or rather more of crystallised carbonate of sodium, and passes
gas through the resulting thin pulpy mass, till the whole of the carbonate o
converted into brown peroxide, amounting to 2½ pts., which may then be
No chloride of lead is formed in this reaction, the whole of the chlorine co
with the sodium, while acetic and carbonic acid are set free.—2. By fusing
of lead with chlorate of potassium at a temperature short of redness.—3. B
ing the red oxide in dilute nitric acid, which dissolves the protoxide, deca
the nitrate of lead, and washing the remaining powder with boiling water
fusing the protoxide for a considerable time with hydrate of potassium, it then
lises in black six-sided tables (Becquerel).—*5.* According to Schönbei
Chem. lxxv. 88), it is obtained, but always mixed with protoxide, when basi
of lead is shaken up with aqueous peroxide of hydrogen or ozonised oil of tur
if, however, the oil of turpentine is in excess, the peroxide is reduced to
with separation of oxygen.—6. When a solution of a lead-salt (nitrate or ac
electrolysed, metallic lead is deposited on the negative, and peroxide of lea
positive electrode.

According to Becquerel (Ann. Ch. Phys. [3] viii. 405), a hydrated peroxid
may be obtained electrolytically.

The peroxide is also said to occur native, as plattnerite, at Leadhills in S
in hexagonal prisms with replaced basic edges, pseudomorphous after pyrom
Cleavage indistinct. Lustre metallic adamantine. Colour iron-black. Streak
Opaque.

The artificially prepared peroxide is a brown powder, which when heated
oxygen, and is converted into red lead or the protoxide. According to Suc
also reduced to the red oxide by exposure to bright sunshine. When touc
the moist hands, it gives off an odour of chlorine or peroxide of hydrogen
hydrochloric acid, it yields chloride of lead and free chlorine; *nitrous acid* co
into nitrate of lead. In an atmosphere of pure *sulphurous anhydride* it beco
hot, and is converted into sulphate of lead, and therefore serves to separate su
anhydride from other gases. With *ammonia* it forms water and nitrate of le
when triturated with one-sixth of its weight of *sulphur*, it takes fire, and burn
bright flame, forming sulphide of lead (Vauquelin); the addition of phosp
of strong sulphuric acid causes a strong detonation (Grindel). *Organic s*
are rapidly oxidised by it; when triturated with crystallised *tartaric acid*, it
red-hot, and eliminates carbonic anhydride and formic acid (Walker).
grape sugar, vivid ignition likewise takes place; also with *mannite*, or with ⅛t
sugar. *Racemic acid*, and especially *gallic acid*, also take fire in contact w
less violent action takes place with *mucic* and *oxalic* acids, carbonic anhydr
formed in the latter case (Böttger). The peroxide likewise oxidises orga
pounds in presence of water; thus it converts *uric* acid into allantoïn a
forming at the same time oxalate of lead and carbonic anhydride (Lie
Wöhler). Boiled with *grape-sugar* and water, it oxidises the sugar, p
formic acid and carbonate of lead. (Stürenburg.)

According to Munck af Rosenschöld, it is the strongest of all negativ
motors (ii. 421).

Peroxide of lead does not unite readily with *acids;* compounds of this o
acetic, phosphoric, arsenic acid, &c., may however, be produced by treating
with the respective acids. (See p. 553.)

The prismatic crystals of acetate of peroxide of lead, or peroxyp
acetate, which separate from a solution of red lead in glacial acetic acid may
to a certain extent between bibulous paper, but if the paper be renewed to
the drying, the crystals turn yellow, and are resolved into acetic acid and the b
oxide; if still moist with acetic acid, they may be kept undecomposed in close
They melt at 160°, and at a somewhat higher temperature, decompose qui
completely, leaving metallic lead, and emitting an odour of acetone and ace
When moistened with water, they are resolved into acetic acid and peroxide
the latter may be obtained pure by washing them with hot water. This

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ing between the solution of the crystals of peroxy-
hat of the sesquioxide in the same acid, as the
nd acetic acid, a certain quantity of neutral acetate
ie water. (Jacquelain. J. pr. Chem. liii. 151.)
phosphate is obtained by dissolving minium in
osphoric acid, and precipitating the dissolved pro-
The solution may be facilitated by mixing the
ric, or acetic acid. Peroxyplumbic phosphate is
n boiling the solution, oxygen is rapidly evolved,
lved, without separation of peroxide. The same
common temperatures. Phosphoric acid added to
increases its stability, and prevents the separation
e nate may be obtained in like manner, but it is
ie phosphate.—A concentrated solution of tartaric
p peroxide, and a clear solution may be decanted
eroxide is quickly decomposed, its oxygen oxidis-
d a precipitate of ordinary tartrate of lead being

s more readily than with acids, behaving towards
erefore be called plumbic acid.
$^2.3H^2O$ or $K^2PbO^3.3H^2O$, is obtained in small
n excess of hydrate of potassium, and dissolving
f water. The solution, evaporated in a vacuum,
my, J. Pharm. [3] iii. 32). It may also be pre-
lver dish with very strong potash-ley, till a sample
precipitate of the peroxide on addition of nitric
upon the hot mass, and the resulting solution is
deposits plumbate of potassium in octahedrons
composed by a small quantity of water, yielding
that oxide in the excess of alkali, which, however,
f water, the whole of the peroxide being precipi-

assium forms with metallic salts precipitates of

by digesting nitrate of lead at 57° for five hours,
f lime. A colourless insoluble compound is then
the lime, leaving pure peroxide of lead. (Crum,

. $Pb^2Br^2O = PbBr^2.PbO$.—This compound is
n contact with the air till it ceases to emit white
ocarbonate of lead (p. 540), till all the carbonic
by immersing bromide of lead for some days in a
from time to time. It is a yellow powder, which
nse white fumes, and solidifies on cooling to a
mass. When decomposed at a high temperature
hloride of lead.

F. Chloride of lead unites in five different pro-
the following compounds:
parts of chloride of lead ignited with one part
rl-grey mixture, which when triturated with water
ie above composition. (Vauquelin.)
compound occurs native as matlockite, in
tlock in Derbyshire. It forms dimetric tabular
oP . ∞P∞ . P . 2P∞. Angle P : P in the ter-
l edges = 120° 52′. Cleavage basal, not perfect.
gravity = 7·21—5·3947. Lustre adamantine,
llowish, sometimes a little greenish. Transparent
[4] ii. 120; Rammelsberg, Pogg. Ann. lxxv.

igniting chloride of lead in contact with the air,
hloride and carbonate of lead together. Carbonic
compound is formed which is deep yellow while
non-yellow colour, and becomes nacreous and cry-
so obtained as a hydrate. $2Pb^2Cl^2O.H^2O$, when
l is digested in a cold solution of neutral acetate
mon salt is dropped into the neutral acetate. The

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precipitate when heated gives off its water and melts to a deep yellow mass, nearly white on cooling.

Pattinson prepares this oxychloride on the large scale, for use as a pigme following process:—Finely pulverised galena is heated with strong hydrochl whereby chloride of lead is formed, and sulphydric acid evolved; this gas i in large gasometers, and used for the preparation of sulphuric acid by coml the ordinary lead-chambers. The liquid is allowed to cool completely in co the undissolved residue; this residue, which consists chiefly of chloride of lead, with cold water to remove the easily soluble chlorides of copper and iron, gradually introduced into a vessel containing boiling water, which diss chloride of lead, leaving a smaller residue consisting of gangue, chloride of s undecomposed galena. By melting this last residue with lime, a quantity containing a little lead is obtained, even from ores in which the proportion o too small for profitable extraction, either by the ordinary process of calcinati Pattinson's condensation process. The hot clear solution of chloride of lead as above is mixed with very thin milk of lime, sufficient to neutralise only ha drochloric acid present. A precipitate of oxychloride, Ppb^2Cl^2O, is then form may be used advantageously as a pigment in place of white lead, as it covers mixed with oil, and does not turn yellow in the dark, or blacken from expos containing sulphuretted hydrogen, more quickly than white lead.

c. $Pb^3Cl^2O^2 = PbCl^2.2PbO$.—This compound forms the rare mineral m (also called *berzelite* and *cerasite*) found on the Mendip Hills in Somersetsh it occurs in yellowish-white, trimetric prisms exhibiting the faces, oP, ∞ ∞P∞, and having the angle ∞P : ∞P = 102° 36′. Cleavage very distinc to ∞P; less distinct diagonally. Hardness = 2·5—3. Specific gravity = The crystals are translucent, and have an adamantine lustre on the cleavage- occurs in a state of greater purity at Brilon, near Stadtbergen in Westph crystals there found are white, translucent, and have a mother-of-pearl the cleavage-faces. It is also found in opaque prismatic crystals at Tar Silesia.

d. $Pb^4Cl^2O^3 = PbCl^2.3PbO$.—This compound is obtained in the anhydrou fusing 1 at. chloride of lead with 3 at. of the protoxide; also as a hydrate, H^2O, by decomposing chloride of lead with ammonia; by precipitating bas of lead with common salt; and by decomposing a solution of common protoxide of lead. The hydrate is a white flocculent mass, and when igni the anhydrous compound, which is a greenish-yellow laminated mass, yieldin powder, known as *Turner's yellow*. It is prepared as a pigment, by mixin with ¼ to ⅓ of its weight of common salt, and pouring water on the mixtur becomes hot, swells up, yields a solution of caustic soda containing a v quantity of lead, and a residue of basic chloride, which is washed and ign moderate heat. The hydrated compound was formerly used as a white p place of white lead, being known as *Pattinson's monobasic chloride;* but it much body as white lead.

e. $Pb^6Cl^2O^5 = PbCl^2.5PbO$.—Obtained by fusing chloride of lead with 5 protoxide. Orange-yellow substance, yielding a deep yellow powder.

f. $Pb^8Cl^2O^7 = PbCl^2.7PbO$.—Produced by fusing a mixture of 10 pts. of p of lead and 1 pt. of pure sal-ammoniac, a portion of the lead being at the reduced. The fused product affords cubic crystals on cooling slowly. It forn state a beautiful yellow pigment, known as *Cassel yellow.*

LEAD, OXYCYANIDE OF. See ii. 253.

LEAD, OXYFLUORIDE OF. See p. 547.

LEAD, OXYGEN-SALTS OF. Protoxide of lead is a strong bas readily with acids, and forming salts, the general characters of which have be described (p. 540). Those which are soluble have a sweetish taste and are They resemble the salts of barium and strontium in being readily precipitat phuric acid, and many of them are isomorphous with the corresponding salt metals. Lead has a very great tendency to form basic salts, which may be either as compounds of the normal salts with oxide or hydrate of lead, o derived from two or more molecules of water, in which less than half the h replaced by an acid radicle: thus, there is a basic nitrate of lead

$$Pb(NO^3)^2.PbH^2O^2 \text{ or } \left.\begin{matrix} NO^2 \\ Pb'' \\ H \end{matrix}\right\} O^2,$$

and a tribasic acetate containing

$$Pb(C^2H^3O^2)^2.(PbO)^2 \text{ or } \left.\begin{matrix} (C^2H^3O)^2 \\ Pb''^3 \end{matrix}\right\} O^4.$$

These basic oxygen-salts are analogous to the oxychlori iodides, &c. (For descriptions of the individual salts, see the several Acids

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The sesquioxide and peroxide of lead also unite with acids, but the salts thence resulting are not very stable. They are produced by the action of certain acids on the red oxide of lead (p. 553).

LEAD, OXYIODIDES OF. Five of these compounds have been described:

a. $Pb^3I^2O = PbI^2.PbO$, is obtained, according to Brandes and Kühne (Pharm. Centralbl. 1847, p. 593), by precipitating acetate of lead with iodide of potassium. Denot (J. Pharm. xx. 1) uses a solution of the neutral acetate mixed with a small quantity of basic acetate, and dissolves out the iodide of lead contained in the precipitate with water. The same compound is said to be formed when iodide of lead is digested for some time in a solution of the neutral acetate. Acetic acid is said to dissolve out the oxide of lead from this compound, leaving the iodide. By immersion in solution of iodide of potassium it is converted into iodide of lead. It contains 1 at. water, which is given off at 100° (Kühne), at 200° (Denot). It melts with partial decomposition at 300°, and solidifies to a clear yellow glass on cooling.

b. $Pb^5I^2O.H^2O = PbI^2.2PbO.H^2O$, is obtained, according to Kühne, by digesting levigated oxide of lead with a boiling solution of iodide of potassium as long as it continues to increase in weight. By precipitating basic acetate of lead with iodide of potassium, Kühne obtained nothing but the compound *a*, whereas Denot states that compounds containing 2 at. and 5 at. oxide of lead to 1 at. iodide are obtained by precipitating iodide of potassium with dibasic or pentabasic acetate of lead.

c. $PbI^2.3PbO.2H^2O$.—Obtained by treating a boiling solution of iodide of lead with caustic ammonia. (Kühne.)

d. $PbI^2.2PbO.Pb^2O^3$ (?).—This is a wine-red compound, obtained by triturating recently precipitated hydrate of lead with a fourth of its weight of iodine, and boiling with water as long as fumes of iodine are given off. (Jammes.)

e. $PbI^2.6PbO$.—Remains in the form of a yellow powder when the compound *d* is dried and heated. (Handw. d. Chem. 2te Aufl. ii. [2], 60.)

LEAD, PHOSPHIDE OF. *a.* When phosphorus is thrown upon melted lead, or when lead-filings are ignited with an equal weight of glacial phosphoric acid, or chloride of lead with phosphorus, a compound is formed containing not more than 15 per cent. of phosphorus: it has the colour of lead; may be cut with a knife, but splits into laminæ when hammered; tarnishes quickly when exposed to the air; and, when heated before the blowpipe, yields a phosphorus-flame and a globule of lead (Pelletier, Ann. Ch. Phys. [2], xiii. 114).—*b.* Phosphoretted hydrogen gas passed for two hours through a solution of neutral acetate of lead, yields a brown precipitate, which burns before the blowpipe with a small phosphorus-flame, forming beautifully crystallised lead-phosphate. (H. Rose, Pogg. Ann. xxiv. 326.)

LEAD, SELENIDE OF. Very small quantities of selenium combined with lead render it harder and less fusible.

The *protoselenide*, PbSe, is formed when lead and selenium are heated together, combination then taking place attended with incandescence, and a grey porous mass being formed, which becomes silver-white by polishing. When ignited in an open vessel, it first gives off selenium, then a small quantity of selenide of lead in white fumes, leaving a residue of basic selenite of lead. Cold nitric acid dissolves the lead, leaving red selenium, which, on heating the liquid, dissolves in the form of selenious acid. (Berzelius.)

Selenide of lead also occurs native, as clausthalite, sometimes pure, sometimes having part of the lead replaced by other metals, as cobalt, copper, mercury, and silver. It is found in fine-grained masses, sometimes foliated, with cubic cleavage. Hardness = 2·5 to 3. Specific gravity = 7 to 8·8. Lustre metallic. Colour lead-grey, sometimes bluish; cupreous varieties yellowish. Streak darker. Opaque. Fracture granular and shining. Rather sectile. Before the blowpipe it emits the odour of horse-radish and exhibits various other reactions characteristic of selenium (*q. v.*). Heated in a tube it yields a sublimate of selenium.

The following are analyses of clausthalite and its varieties:—*a*, H. Rose (Pogg. Ann. ii. 416; iii. 281); *b*, Stromeyer (*ibid.* ii. 403); *c*, Selenide of lead and silver (Rammelsberg, *Mineralchemie*, p. 34); *d*, Selenide of lead and cobalt; *e*, *f*, Selenides of lead and copper (H. Rose, Pogg. Ann. iii. 288); *g*, *h*, The same (Kersten, *ibid.* xlvi. 265):

	Tilkerode.	Clausthal.	Tilkerode.	Clausthal.	Tilkerode.		Glasbach.	
	a.	*b.*	*c.*	*d.*	*e.*	*f.*	*g.*	*h.*
Selenium	27·59	28·11	26·52	31·42	34·98	30·26	32·09	29·97
Lead	71·81	70·98	60·15	63·92	48·43	60·28	57·48	65·16
Silver	. .	. .	11·67	. .	1·32			
Cobalt	. .	0·83	. .	3·14	. .	. .	0·05	0·08
Copper	. .	. .	. .	. .	15·77	7·94	8·58	4·09
Iron	. .	. .	. .	0·45	. .	0·78		
	99·40	99·92	98·34	98·93	100·50	99·26	98·20	99·30

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The varieties *e*, *f*, *g*, *h*, which contain copper, are by some mineralogists rega distinct species; but it is perhaps better to regard them as varieties of claustha which part of the lead is replaced by copper; *e* and *f* are called *raphanos* Kobell; *d* is called *Tilkerodite* by Haidinger; *d*, *e*, and *f* are called *Zorgite* by and Miller; *e* and *h* agree nearly with the formula $\left.\begin{matrix}\frac{1}{2}\mathrm{Pb}\\ \frac{1}{2}\mathrm{Cu}\end{matrix}\right\}\mathrm{Se}$; *f* and *g* with $\left.\begin{matrix}\frac{3}{5}\mathrm{Pb}\\ \frac{2}{5}\mathrm{Cu}\end{matrix}\right\}$

Clausthalite and its varieties occur at Harzgerode, in the Hartz, and at Cl Tilkerode, Zorge, Glasbach, near Hildburghausen, and Lehrbach; also at Ra and Freiberg in Saxony.

Lehrbachite, which is a selenide of lead and mercury, and is described as hav structure and colour of clausthalite, is, perhaps, a mechanical mixture of that with selenide of mercury. It emits the odour of selenium before the blowpi gives mercury with soda. H. Rose found in one specimen 24·97 per cent. se 55·84 lead, and 16·94 mercury (=97·75); in another, 27·98 selenium, 27·33 le 44·69 mercury (=100).

LEAD, SULPHIDES OF. There are four compounds of lead and s namely, the protosulphide, two subsulphides, and a persulphide; but the protos is the only one whose constitution is accurately known.

Tetartosulphide. Pb^4S?—A finely divided mixture of 100 pts. of galena of lead heated for a quarter of an hour in a well-closed charcoal-lined crucible, in a wind-furnace with a strong draught, yields 144 pts. of a dull, lead-co fine-grained, semi-malleable, soft mixture, exhibiting a dark-grey colour on surface. When oxidised by nitric acid, it yields 36 per cent. of lead-sulpha must therefore contain 3·96 per cent. of sulphur. (Bredberg, Pogg. Ann. xvi

Hemisulphide. Pb^2S.—1. By the same process as for the preceding comp excepting that the mixture is fused in an earthen instead of a charcoal-lined c and covered with borax—150 pts. of a more brittle mixture are obtained, h dark leaden-grey colour, a finely laminar fracture, and containing 7·207 per sulphur (Bredberg).—2. Sulphate of lead ignited in a charcoal-lined crucibl off sulphurous anhydride and leaves hemisulphide of lead, which at a higher te ture, partly volatilises and is partly decomposed, leaving a residue of metall (Berthier, Ann. Ch. Phys. [2] xxii. 240.)

Protosulphide. PbS.—This compound is found native as galena (*bl galène*, *Bleiglanz*), the most abundant and important ore of lead. It occu quently in very fine crystals belonging to the monometric system, with cleavage, perfect and easily obtained. The ordinary forms are the octahedron and rhombic dodecahedron, occurring alone or in combination with other forms, example, subordinate; twins like *fig.* 320 (ii. 160), and others in which the ir ting cubes are of different sizes, or in which the diagonals do not exactly co also pseudomorphs after pyromorphite. The crystals are frequently imbedded, or u granular aggregations. The mineral likewise occurs in tabular, reniform or bot masses, coarse or fine granular, sometimes impalpable, occasionally fibrous. H = 2·5. Specific gravity = 7·25 to 7·7. Lustre metallic. Colour and strea lead-grey; surface of crystals occasionally tarnished. Fracture scarcely perc in the crystals, on account of the perfect cleavage; in the massive varieties, fl conchoïdal, or uneven. Before the blowpipe, it decrepitates strongly, melts and a globule of lead as soon as the sulphur is volatilised.

For analyses of galena, see p. 480.

Galena is found abundantly in England and in many parts of Europe; in the I Mountains, Siberia; in Algeria; near the Cape of Good Hope; in Australia; many parts of North America. It occurs in beds and veins, both in crystalli uncrystalline rocks, often associated with blende, iron and copper pyrites, ca of lead and other lead ores, and in a gangue of heavy spar, calcspar or quar often suffers decomposition, and gives rise to the formation of other plumb minerals.

Breithaupt's antimonial galena from Freiburg in the Breisgrau, with s gravity = 6·9 to 7·0, is perhaps the same as steinmannite from Przibram hemia. Whether the tetragonal galena of the same mineralogist, also cont antimony, is a dimetric variety of galena, is not exactly known.

Protosulphide of lead is produced artificially:—1. When sulphur is mixe melted lead, the whole becoming red-hot. Strips of lead even of moderate thi take fire in sulphur-vapour, and burn with vivid glow, depositing half-fused gl of the protosulphide.—2. By heating the protoxide with excess of sulphur.—3. action of sulphydric acid or an alkaline sulphide on the oxide or salts of l 4. Becquerel, by immersing cinnabar in a solution of chloride of magnesium contain glass tube, dipping a lead plate to the bottom, and leaving the tube well closed

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weeks, obtained grey, metallic-shining, regular tetahedrons of the protosulphide, which formed on the sides of the tube.

Sulphide of lead obtained by fusing its elements together is of a lead-grey colour, with granular fracture; that which is precipitated by sulphydric acid is a brown-black powder, and, according to Karsten, has a density of 7·5052 after fusion. Sulphide of lead melts at a strong red heat, volatilises at a stronger heat, and sublimes undecomposed if kept from contact with the air.

Decomposition.—1. Sulphide of lead, when gently ignited in the air, gives off the greater part of its sulphur in the form of sulphurous anhydride, while metallic lead (amounting to about half the total quantity) and sulphate of lead remain behind (Descotils, Ann. Ch. Phys. [2] lv. 441).—2. The protosulphide and protoxide of lead decompose one another when heated together, evolving sulphurous anhydride and leaving metallic lead:

$$PbS + 2PbO = Pb^3 + SO^2.$$

—3. The protosulphide heated in vapour of water gives off sulphydric acid and yields metallic lead. The first products formed are sulphydric acid and the protoxide, which then reacts on the remaining sulphide in the manner just described.—4. When sulphide of lead is fused with alkaline carbonates, half the lead is separated in the metallic state, and on addition of metallic iron, the whole.

Protosulphide of lead is insoluble in *dilute acids*, in caustic *alkalis*, and *alkaline sulphides*. When boiled with *dilute nitric acid* it gradually dissolves as nitrate, with evolution of nitric oxide, and separation of sulphur. The finely divided sulphide treated with *fuming nitric acid* is completely converted into sulphate of lead: but if any portion of the sulphur remains unoxidised, a corresponding quantity of the lead is converted into nitrate. By strong *hydrochloric acid* it is converted into chloride of lead with evolution of sulphydric acid. *Nitro-hydrochloric acid* converts it into chloride and sulphate of lead. *Chlorine* decomposes it slowly, forming chloride of lead and chloride of sulphur.

Persulphide. A solution of a lead-salt mixed with pentasulphide of potassium yields a precipitate, which has at first a fine blood-red colour, but quickly loses this colour, even while immersed in the liquid, and is resolved into the protosulphide and free sulphur. Higher sulphides of lead are also said to be formed by the action of sulphydric acid on the sesquioxide and peroxide of lead; but their composition has not been made out.

LEAD, SULPHOCARBONATE OF. See SULPHOCARBONATES.

LEAD, SULPHOCHLORIDE OF. If a lead-salt, *e.g.* aqueous chloride of lead, be precipitated by a mixture of aqueous sulphydric and hydrochloric acids, there is produced, first a yellowish-red, and then a red precipitate containing about 56 per cent. (3 at.) of lead-sulphide, and agreeing very nearly with the formula, $PbCl^2.3PbS$. An excess of sulphydric acid turns it black and converts it into pure sulphide of lead; the same change is produced by boiling with water, which extracts the chloride; the compound is also blackened by potash, which extracts the chlorine (Hünefeld, J. pr. Chem. vii. 27).—When sulphydric acid gas is passed through a solution of ½ pt. lead-acetate in 100 pts. of water mixed with 10 pts. of hydrochloric acid of specific gravity 1·168, a beautiful carmine-coloured precipitate of sulphochloride of lead is produced If the solution contains 1 pt. of lead-acetate, 112 pts. of water, and 14 of strong hydrochloric acid, sulphydric acid produces a yellow precipitate, which gives up chloride of lead to boiling water, while black protosulphide of lead remains behind. If, instead of 14 pts. of strong hydrochloric acid, we use 14 pts. of a mixture of 2 pts. of strong hydrochloric and 1 pt. nitric acid, prepared two days before and containing pernitric oxide, the sulphydric acid produces, after a while, first a yellowish-red and then a cinnabar-red, granular precipitate. If the stream of sulphydric acid gas were continued for a longer time, the precipitate would become first carmine-coloured, then brown, and lastly black. The red granular precipitate, when boiled with water, gives up a considerable quantity of chloride of lead, and is converted into a brown-red, flocculent powder, which then undergoes no further change, but when heated alone in a glass tube, gives off sulphur and sulphydric acid, and fuses to a brown mass. According to this reaction, the pernitric oxide must have precipitated sulphur from the sulphydric acid, and the red precipitate is a compound of the chloride with a polysulphide of lead. (Reinsch, J. pr. Chem. xiii. 130.)

LEAD, SULPHOCYANATE OF. See SULPHOCYANATES.

LEAD, WHITE. Hydrated carbonate of lead used as a pigment (ii. 786). The native anhydrous carbonate is also called white lead ore.

LEAD-GLANCE. Syn. with galena (see p. 558).

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LEAD-GLASS. *Vitrum plumbi.*—A term formerly applied to perf
oxide of lead. Oxide of lead is used as an ingredient in various kinds of g
flint-glass, crystal-glass, strass, &c. (ii. 841).

LEAD-GLAZE. The glaze of the more common kinds of earthenware
an easily fusible silicate of lead, prepared from a mixture of finely ground
litharge, white lead, or galena, with clay or sand. It melts more easily in
as it is richer in lead, but when the proportion of lead is very large, the glaz
posed by dilute acids, which dissolve part of the oxide of lead.

LEADHILLITE. *Sulphato-tricarbonate of lead,* $PbSO^4.3PbCO^3$ =

—A crystallised mineral occurring, together with other ores of lead, at L
Scotland; said also to be found in Grenada, in the island of Serpho, Greci
pelago, and in the Newberg district, South Carolina. The crystals are
exhibiting the planes $\infty\breve{P}\infty$ (greatly predominant), $\infty\breve{P}\infty$, ∞P, $\frac{4}{3}\breve{P}\infty$, $\frac{4}{3}$
$\frac{1}{3}$ P and others. Angle $\infty P : \infty P = 103° 16'$. Ratio of principal axi
diagonal and macrodiagonal = 1·7205 : 1 : 1·2632. The crystals are
in ∞P and some other planes; hence they are monoclinic in aspect, or rho
when in compound crystals. Cleavage very perfect parallel, to $\infty\breve{P}\infty$; in trac
to $\infty\breve{P}\infty$. Twins consisting of three crystals, with face of composition $\breve{P}\infty$;
lel to ∞P. Hardness = 2·5. Specific gravity = 6·2—6·5. Lustre of $\infty\breve{P}\infty$
the other faces resinous, somewhat adamantine. Colour white, passing in
green, and grey. Streak uncoloured. Transparent to translucent. Conch
ture scarcely observable. Rather sectile. Before the blowpipe, it intumesc
then turns yellow, but becomes white on cooling; easily reduced on cha
effervesces briskly in nitric acid, and leaves a white residue of lead-sulphate
Berzelius found in the mineral 28·7 per cent. sulphate, and 71·0 carbona
(= 99·7); Stromeyer found 28·3 sulphate, and 72·7 carbonate (= 100); th
requires 27·44 sulphate and 72·56 carbonate. (Dana, ii. 371.)

LEAD-MATT. *Matte de plombe. Bleistein.*—This term is applied t
tures of sulphide of lead with other metallic sulphides, chiefly sulphide of iron
in the metallurgic treatment of lead-ores (p. 492).

LEAD-OCHRE. Native protoxide of lead (p. 550).

LEAD-PLASTER. A mixture of the lead-soaps of fatty acids, used
cine as an external application. It is prepared by heating 9 pts. o
(sometimes also lard or rape-oil) nearly to its boiling-point, then adding
5 pts. of powdered litharge, incorporating thoroughly with a spatula, ad
time to time small portions of warm water, and continuing the heating
poration till a few drops of the mixture harden when thrown into water, a
glutinous mass between the fingers. Sometimes a mixture of litharge and
is used instead of litharge alone.—Well-prepared lead-plaster forms a whit
homogeneous mass, somewhat flexible and tenacious in summer, brittle in wint
gently heated, it melts to a thick liquid, which, at higher temperatures, tur
and finally black, giving off irritating vapours.

LEAD-RADICLES, ORGANIC. These compounds, the series of w
present far from complete, are obtained by the action of the iodides of th
radicles on lead or its alloys with potassium or sodium, or of zinc-ethyl on
lead. The formation of ethyl-compounds by the first of these processes
observed in 1853 by Löwig (J. pr. Chem. lx. 304; Ann. Ch. Pharm lxxx
soon afterwards by Cahours and Riche. (Compt. rend. xxxvi. 1002.)
The iodide of the radicle $Pb^2(C^2H^5)^6$ was discovered by Löwig, who desig
radicle methplumbethyl, and studied several of its compounds, but did
it in the free state. It has since been isolated (1860) by Klippel (J.
lxxxi. 287), who has likewise obtained the corresponding amyl-compou
compound $Pb(C^2H^5)^4$ was discovered in 1858 by Buckton (Phil. Mag.
212, xvii. 282; Ann. Ch. Pharm. cix. 218, cxii. 220); and the corr
methyl-compound by Cahours in 1861 (Ann. Ch. Phys. [3] lxii. 257;
Pharm. cxxii. 48), who likewise obtained by its decomposition, the
$Pb^2(CH^3)^6$.

Amyl-compounds.

Plumbotriamyl. *Methplumbamyl.* $Pb^2(C^5H^{11})^6 = Pb^2Am^6$.—Prepared
corresponding ethyl-compound) by distilling an alloy of lead and sodium w
of amyl. shaking up the distillate with ether, distilling off the ether after a

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a little alcohol, and treating the residue with a large quantity of water. Plumbotriamyl then separates as a yellowish, oily, non-volatile liquid, inodorous in the cold, smelling like plumbotriethyl when warm: its vapour exerts an irritating action on the mucous membranes. When set on fire it burns, with separation of lead-oxide. With fuming nitric acid it detonates, with emission of light and heat.

The *chloride*, $PbAm^3Cl$, is obtained by treating the oxide (*infra*) with hydrochloric acid. It crystallises in white needles.

The *iodide*, $PbAm^3I$, is obtained in white needles by adding iodine to the ethereal solution of plumbotriamyl, till the colour becomes permanent, and evaporating the filtrate. It is more stable than the corresponding ethyl-compound, melting at 100° without decomposition, and solidifying in the crystalline form on cooling. It is insoluble in water. It unites with *mercuric iodide*, forming the double salt $PbAm^3I.HgI^2$, which crystallises in golden-yellow laminæ, insoluble in water, sparingly soluble in alcohol and ether.

Oxide.—By agitating the alcoholic solution of the iodide with recently precipitated oxide of silver, evaporating the filtrate, and treating the residue with water, oxide of plumbotriamyl separates as a faintly yellow viscid mass, insoluble in water, soluble in alcohol and ether; the alcoholic solution has a faint alkaline reaction, and precipitates ferric salts, but not copper or silver salts.

The *sulphate*, obtained by heating the oxide with dilute sulphuric acid, is a viscid uncrystallisable mass. (Klippel.)

Ethyl-compounds.

Plumbotriethyl. $Pb^2(C^2H^5)^6 = Pb^2E^6$. Löwig's *Methplumbethyl.*—Löwig, by acting on an alloy of 6 pts. lead and 1 pt. sodium with iodide of ethyl, obtained a mixture of several lead-compounds of ethyl, which he was not able to separate. The mixture was perfectly colourless, tolerably mobile, volatile, and had a powerful odour; did not fume in the air, but when set on fire burnt and gave off dense clouds of oxide of lead. It took fire when strong nitric acid was poured upon it, and exploded with great violence in contact with iodine or bromine. It was insoluble in water, but dissolved readily in alcohol or ether; and the solutions, when exposed to the air, deposited an amorphous powder, insoluble in water, alcohol and ether, but capable of forming crystallisable salts with acids, while in solution there remained a strongly alkaline base, the oxide of plumbotriethyl, the radicle of which appeared to constitute the greater part of the product. This radicle, however, Löwig did not succeed in isolating.

Klippel prepares an alloy of lead and sodium, having nearly the composition Pb^2Na^2, by melting 3 pts. of lead in a hessian crucible, and after removing it from the fire, adding 1 pt. sodium in small pieces still moistened with rock-oil, and stirring with an iron rod. Combination then takes place, attended with evolution of heat and inflammation of the rock-oil (the gases evolved by which protect the alloy from oxidation). When the action is completed, the crucible is filled with warm sand and left to cool slowly; the crystalline alloy is pulverised in a warm mortar, with addition of a small quantity of dry sand, then introduced into a number of small flasks and drenched with iodide of ethyl, and the flasks are immediately connected with a condensing tube, to prevent loss of iodide of ethyl, which distils over in consequence of the heat evolved by the violent action which immediately takes place. The iodide of ethyl is allowed to flow back into the flasks as long as any action goes on, and when it is completed the excess of iodide of ethyl is distilled off over the water-bath; the remaining liquid is poured out of the flasks into a dry glass cylinder and shaken up with ether, which dissolves the plumbotriethyl; and the ether is distilled off after addition of a little water: the plumbotriethyl then separates as an oil at the bottom of the water.

Plumbotriethyl is a yellowish mobile oil, of specific gravity 1·471 at 0°, insoluble in *water*, easily soluble in *alcohol* and *ether*. It volatilises undecomposed in small quantity with ether-vapour, but cannot be distilled alone. By the action of light, or by prolonged boiling with water, it decomposes, with separation of metallic lead (Klippel). When exposed to the air in ethereal solution, it is converted into oxide (Löwig), carbonate (Klippel). *Chlorine-water* decomposes it, with separation of chloride of lead. (Klippel.)

Bromide of plumbotriethyl, PbE^3Br, is obtained by adding an alcoholic solution of bromide of potassium to a solution of the sulphate in alcohol containing sulphuric acid, agitating the whole with ether, then with water to separate the ethereal solution, and evaporating the ether; it then crystallises in long needles. (Löwig.)

The *chloride*, PbE^3Cl, is obtained by adding chloride of barium to a solution of the sulphate in alcohol containing hydrochloric acid, agitating with ether, separating the ethereal solution by water, and leaving it to evaporate (Löwig); by neutralising

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the oxide or carbonate with hydrochloric acid (Klippel); or by the action of chloric acid gas on plumbotetrethyl (Buckton, p. 563). It crystallises in b long needles, having a high lustre, and giving off a strong odour of oil of when gently heated. When heated in a glass tube, they detonate slightly, e moderate heat, yielding chloride of lead and metallic lead. (Löwig.)

The *chloromercurate*, $PbE^3Cl.HgCl^2$, separates from a hot alcoholic sol the component salts in white nacreous scales; the *chloroplatinate*, $2PbE^3C$ in copper-red crystals, sparingly soluble in water, more easily in alcohol an (Klippel.)

The *cyanide*, $C^7H^{15}NPb = PbE^3Cy$, is obtained by heating cyanide of po with an alcoholic solution of chloride of plumbotriethyl, for a considerable ti sealed tube placed in a water-bath, mixing the resulting blood-red liquid wit and recrystallising the resulting white precipitate from ether. It then sepa prismatic crystals, which, when heated in a tube, melt and decompose, with defla separation of metallic lead, and evolution of inflammable vapours. (Klippe

The *iodide*, PbE^3I, formed by the action of iodine on plumbotriethyl (Kl or by the reaction of iodide of potassium and sulphate of plumbotriethyl (Lö soluble in ether and very unstable, the ethereal solution quickly yielding a de iodide of lead.—If the compound, while yet undecomposed, be distilled with wate of lead separates immediately, and the water which passes over is accompan colourless, mobile, very pungent liquid, no longer prone to spontaneous decomp and having nearly the composition $(PbE^3)^4I^3$. (Löwig.)

Oxide of plumbotriethyl is obtained in the hydrated state by adding a of nitrate of silver mixed with alcohol to the alcoholic solution of the mixed as long as metallic silver is precipitated; filtering from the silver; agitating th ing solution of nitrate of plumbotriethyl with alcoholic potash and afterwards wit adding a sufficient quantity of water to separate the ethereal solution of the oxi evaporating the ether in a retort. Hydrated oxide of plumbotriethyl then re the form of a thick oily liquid, which solidifies after a while in a crystalli slippery to the touch, like hydrate of potassium (Löwig). It may also be prep gradually adding iodine to the ethereal solution of plumbotriethyl till the c longer disappears, and immediately agitating the liquid with moist oxide of sil alkaline solution is thus obtained which, on addition of water and remova alcohol and ether by distillation, deposits hydrate of plumbotriethyl as a nearly co thickish oil (Klippel). It is volatile, and forms white fumes when a rod m with hydrochloric acid is held over it. When heated, it gives off white vapour excite powerful sneezing—a property which also belongs to the radicle itself an of its compounds. The hydrate dissolves sparingly in water, readily in alcoho ether; has a strong alkaline reaction, and a sharp, disagreeable, caustic taste (Klippel); saponifies fats; precipitates the oxides of iron, copper and silver fr salts; also alumina and oxide of zinc, both of which it redissolves when a excess. (Klippel.)

Oxygen-salts. The oxide unites readily with acids, forming crystallisable

The *acetate*, *benzoate*, and *butyrate* form needle-shaped crystals, soluble in alcohol, and ether.

Carbonate, $Pb^2E^6CO^3$.—The hydrated oxide rapidly absorbs carbonic ac the air, and by leaving the alcoholic solution to evaporate in the air, the carb obtained in small hard crystals (Löwig); or it may be prepared by passing anhydride into the solution, and separated by addition of carbonate of ammo being taken however to avoid an excess of the latter, which would give rise to th tion of an easily soluble double salt. Carbonate of plumbotriethyl has a strong taste, is nearly insoluble in water, sparingly soluble in alcohol and ether. containing hydrochloric acid dissolves it with effervescence. (Löwig.)

Formate of plumbotriethyl resembles the acetate.

The *nitrate*, PbE^3NO^3, is obtained by decomposing the alcoholic solution mixed plumbethyls (Löwig, p. 561), or the ethereal solution of pure plumb (Klippel) with nitrate of silver. It remains on evaporation as a colourles liquid, which smells like butter, has a burning taste, and solidifies after a wh crystalline unctuous mass. It is decomposed by heat, with slight detonat dissolves readily in alcohol and ether; the alcoholic solution when evaporated, a small quantity of nitrate of lead. (Löwig.)

The neutral *oxalate* forms scaly laminar crystals, which when dried over oil o contain $C^2(PbE^3)^2O^4.H^2O$. (Klippel.)

A *phosphate* $(PbE^3)H^2PO^4$, is obtained, by saturating the oxide or carbon phosphoric acid, in stellate groups of crystals which dissolve readily in water, and ether, and are oxidised with vivid deflagration, when treated in the dry st fuming nitric acid. (Klippel.)

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Sulphate. $(PbE^2)^2SO^4$.—When sulphuric acid is added by drops to an alcoholic solution of the oxide, leaving the base in excess, a dazzling white crystalline precipitate of the sulphate is obtained, which must be washed with alcohol and afterwards with ether. The salt is nearly insoluble in water, absolute alcohol, and ether, but dissolves readily in alcohol mixed with sulphuric or hydrochloric acid. From the acid solution it crystallises in tolerably large, hard, shining octahedral crystals (Löwig). Klippel, by dissolving the carbonate in alcoholic sulphuric acid, obtained the sulphate in crystals like those of quartz. Buckton, by decomposing the chloride with sulphuric acid or sulphate of silver, obtained it in asbestiform needles.

The *acid tartrate*, $C^4H^4(PbE^2)O^6$ (at 100°), forms scaly laminar crystals.

Sulphide of plumbotriethyl is obtained by treating a solution of the oxide or a salt of plumbotriethyl, with sulphydric acid or sulphide of ammonium, as a white precipitate, which is nearly insoluble in water, alcohol, and ether, and blackens quickly with separation of sulphide of lead. (Klippel.)

The *sulphocyanate* is formed by heating an alcoholic solution of the chloride with recently precipitated sulphocyanate of silver to 100° in a sealed tube. It dissolves in water, alcohol, and ether, and crystallises from the ethereal solution in the same form as sulphocyanate of potassium. (Klippel.)

Plumbotetrethyl. $Pb^2C^8H^{20} = Pb(C^2H^5)^4$ or PbE^4. *Diethylide of lead. Plumbodiethylide* (Buckton).—Produced by the action of zinc-ethyl on chloride of lead:

$$2ZnE^2 + 2PbCl^2 = 2ZnCl^2 + PbE^4 + Pb.$$

When dry chloride of lead is added to zinc-ethyl, decomposition takes place immediately, attended with separation of metallic lead, and slight rise of temperature; and on adding an excess of the lead-chloride, and warming gently for a few minutes, a clear liquid may be decanted, apparently consisting of several lead-radicles combined with zinc-ethyl, which cannot be completely removed by digestion with excess of lead-chloride, but may be expelled for the most part by distillation. The liquid remaining in the retort at 140°-150° yields, when treated with water and hydrochloric acid, heavy colourless drops of a liquid, the greater part of which, consisting of plumbotetrethyl, distils over between 198° and 202°; but the compound is most easily obtained in the pure state by distillation in a rarefied atmosphere. (Buckton.)

Plumbotetrethyl is a transparent colourless liquid of specific gravity 1·62. Under the ordinary pressure it boils with partial decomposition, at a few degrees above 200°, but under a pressure of 7·5 inches of mercury it boils without decomposition at 152°. When set on fire, it burns with pale-green-bordered flame, emitting a fume of lead-oxide. In a stream of hydrochloric acid gas, it is converted into chloride of plumbotriethyl, with evolution of hydride of ethyl:

$$Pb(C^2H^5)^4 + HCl = Pb(C^2H^5)^3Cl + C^2H^6.H. \quad \text{(Buckton.)}$$

Methyl-compounds.

Plumbotrimethyl. $PbC^3H^9 = Pb(CH^3)^3 = PbMe^3$.—This radicle has not yet been obtained in the free state, but its salts are produced, with evolution of hydride of methyl, by treating plumbotetramethyl with acids: *e.g.* with hydrochloric acid, the reaction being precisely similar to that which takes place in the case of the corresponding ethyl compound, as represented by the equation just given.

Chloride of plumbotrimethyl, $PbMe^3Cl$, thus obtained, separates from the solution on cooling in long needles very much like chloride of lead. If the boiling of the plumbotetramethyl with hydrochloric acid be too long continued, chloride of lead is apt to be formed.

Bromide of Plumbotrimethyl is somewhat more soluble than the chloride.

The *iodide*, $PbMe^3I$, is obtained by adding iodine to plumbotetramethyl till the colour becomes permanent (iodide of methyl being probably formed at the same time:

$$PbMe^4 + I^2 = PbMe^3I + MeI).$$

The product is a white solid mass, mixed with yellow iodide of lead, sparingly soluble in water, easily in alcohol, and crystallising in long colourless needles, which may be sublimed. By distillation with caustic potash, it yields the hydrate of plumbotrimethyl, as a strong basic oil, smelling like oil of mustard, and solidifying in prismatic needles. (Cahours.)

Plumbotetramethyl. $PbC^4H^{12} = Pb(CH^3)^4 = PbMe^4$.—Produced by the action of iodide of methyl on an alloy of 5 pts. lead and 1 pt. sodium, or, better, by treating chloride of lead with zinc-methyl. It is a colourless, mobile liquid, having a camphor-like odour, insoluble in water, but soluble in alcohol and ether. It boils at 160°, decomposes at a few degrees above that temperature, but may be distilled with-

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out alteration in a gas which does not act upon it (Cahours). Accord Buttlerow, however, it smells like strawberries or mould, not at all like ca boils at 100°,* and when free from zinc-methyl, may be distilled without de sition in contact with air; in a sealed tube containing chlorocarbonate of ethyl, be heated to 200° without decomposition. Its vapour-density, determined Lussac's method, is 9·66 at 115°, and 9·52 at 130°; calculation = 9·25. It then that the compound is converted into a perfect gas at a temperature ve above its boiling point. (Buttlerow.)

Plumbotetramethyl, like the corresponding ethyl-compound, does not unite with *oxygen*, *chlorine*, or *iodine*, but is decomposed thereby, yielding compo which part of the methyl is replaced by the acting elements, but belonging to t type as plumbotetramethyl itself; *e.g.* iodide of plumbotriethyl, $Pb(CH^3)^3I$, action of iodine. Treated with *acids*, it yields hydride of methyl and a salt of triethyl. (Cahours.)

LEAD-SOAPS. Lead-salts of the fat-acids. Common lead-plaster (p. a preparation of this kind.—Palmer in 1845 patented the preparation of a le for greasing the axles of railway carriages, &c. It is prepared by heating the oleic acid obtained from the manufacture of stearin-candles, and stirring litha it as long as the litharge is dissolved. Before use it is mixed with a certain quanti or tallow.—A compound of lead-oxide with the acids of linseed-oil, prepared by de ing the potash-soap of linseed-oil with solution of acetate of lead, serves, when d in oil of turpentine, for printing on wall-paper, previous to gilding it with gold Dutch metal, or dusting it with wool-shearings for the production of flock-patt

LEAD-SPEISS. The metallurgical name of certain products obtained working of lead-ores containing arsenic or antimony. The following table the composition of two lead-speisses analysed by Bodemann: *a*, from Claus from Andreasberg, and another; *c*, by Ahrend from the Lower Hartz:

	Pb	As	Sb	Cu	Ag	Fe	S	Co and
a.	68·2	. .	30·3	trace	. .	trace	1·5	
b.	90·5	0·1	1·3	0·3	0·1	2·6	5·0	
c.	26·1	13·0	5·2	44·5	0·1	5·5	2·8	2·3

LEAD-VITRIOL. Sulphate of lead (see SULPHATES).

LEAF-GREEN. See CHLOROPHYLL (i. 922).

LEAF-RED. See ERYTHROPHYLL (ii. 506).

LEAF-YELLOW. See XANTHOPHYLL.

LEATHER consists of the skins of animals prepared by a process, or rath of processes, called tanning, by which they are preserved from putrefyin moist, and rendered soft and pliable when dry. The skins are first freed from mis, fatty matter and hairs, by steeping them in milk of lime, or in an acesc fusion of barley- or rye-meal, or spent tan, which sets up a slow fermentat either of these modes of treatment, the epidermis and the cellular tissue in wh hairs are rooted, are disintegrated, so that the hair and epidermis can then b removed by scraping. The skins thus prepared are then steeped in an infusion substance capable of uniting with the true skin and converting it into leathe materials used for this purpose are:

1. *Tannin* or *tannic acid*, in the process of tanning properly so called, w applied chiefly to the stouter kinds of leather, made from the hides of oxen and The true skin of animals is a gelatinous tissue (ii. 826) and gelatin unit tannic acid, forming a tough insoluble substance possessing the properties of (ii. 765). Several substances are used by the tanner as sources of tannic acid; most valuable and most extensively used of all is oak-bark. The followi stances are also used, sometimes alone, but more generally as additions to the oa —Sumach, from the bark of *Rhus cotinus* or *Rhus coriaria*; catechu, or *Terr nica*, chiefly from various species of *Acacia* (i. 816); dividivi, the crushed *Cæsalpinia coriaria*; mimosa, from the bark and pods of various kinds of *Pro* genus of leguminous plants; valonia, the acorn of the great prickly-cupp (*Quercus Ægilops*); and nut-galls.

2. *Alum* and *common salt*, in the process called tawing, which is applied to the lighter kinds of skin, namely these of sheep, goats, and calves.

* This boiling point differs from that of plumbotetrethyl (about 200°) by 90°, or 22·5° for a diff CH^2 in the formulæ, whereas the boiling point of plumbotetramethyl found by Cahours, viz. 160 from 200 by only 40°, or by 10° for each difference of CH^2 in the formulæ. Now on comparing ferences of boiling points in the corresponding methyl- and ethyl-compounds of phosphorus, arse mony, and tin, it is found that the difference always amounts to 20° or upwards for each molecul added to the compound. The boiling point of plumbotetramethyl found by Buttlerow is theref in accordance with analogy than that determined by Cahours.

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3. *Oil*, for the preparation of chamois, shamoy, or wash-leather, which is prepared from the skins of the goat, doe, or chamois, and is a soft, spongy leather, capable of washing.

4. *Lime*, for parchment, which is prepared from calf or sheep skins, and for the stronger kinds, from asses' or pig's skin.

For the details of all these processes we must refer to *Ure's Dictionary of Arts, &c.* (ii. 674—686), and the *Handwörterbuch der Chemie* (iv. 792—810).

LECANORIC ACID. $C^{16}H^{14}O^7$? *Lecanorin. α-Orsellic acid.* (Schunck, Ann. Ch. Pharm. xli. 157; liv. 261; lxi. 72.—Rochleder and Heldt, *ibid.* lxviii. 1. —Stenhouse, *ibid.* lxviii. 61; lxx. 218.—Strecker, *ibid.* lxviii. 13.—Laurent and Gerhardt, Ann. Ch. Phys. [3], xxiv. 315.—Robiquet, Ann. Ch. Phys. xlii. 236; Gm. xii. 377.)—This substance, which was discovered by Schunck in 1842, is extracted from several lichens belonging to the genera *Lecanora* and *Variolaria*. The lichens, in the state of fine powder, are exhausted with ether in a percolator, and, on evaporating the ether, a residue is obtained which is to be washed with ether on a large funnel till it is colourless, then exhausted with water, and crystallised from alcohol (Schunck). Rochleder and Heldt exhaust the lichen (*Evernia prunastri*) with a mixture of ammonia and alcohol, dilute the alcohol with a third of its volume of water, and saturate with acetic acid. Lecanoric acid then separates in grey flocks, which are washed, dried at 100°, dissolved in a small quantity of boiling absolute alcohol, and purified by recrystallisation.

Stenhouse macerates the lichen (*Roccella tinctoria*) with water mixed with slaked lime, precipitates the filtered liquid with hydrochloric acid; washes and dries the gelatinous precipitate, and digests it, when nearly dry, with absolute alcohol, taking care not to boil the liquid, which, on cooling, deposits the acid in crystals.

Lecanoric acid crystallises in colourless stellate needles, sparingly soluble in cold *water* and in cold *alcohol;* moderately soluble in boiling alcohol, soluble in *ether* and in *acetic acid*. According to Schunck, 1 pt. of lecanoric acid requires for solution 2,500 pts. of boiling water, 150 pts. of alcohol of 80 per cent. at 15°; 5·15 pts. of boiling alcohol, and 80 pts. ether at 15·5°. The solution reddens litmus. The crystallised acid does not lose weight at 100°.

Lecanoric acid gives by analysis 59·45 to 60·59 carbon, and 4·40 to 5·00 hydrogen, whence Stenhouse deduced the formula $C^{16}H^{14}O^7$, which Gerhardt altered to $C^{18}H^{14}O^7$ (60·37 per cent. C, 4·40 H, and 35·23). This latter formula readily explains the conversion of lecanoric into orsellic acid (*infra*).

Lecanoric acid yields by dry distillation, a viscid oil, together with orcin. It dissolves readily at ordinary temperatures in lime-water or baryta-water, and is precipitated therefrom by acids in the form of a jelly, and without alteration; but if the saturated solution be boiled, the lecanorate of barium or calcium changes into the much more soluble *orsellinate*. If the ebullition be prolonged, carbonate of barium or calcium is precipitated, and *orcin* remains in solution:

$$\underset{\text{Lecanoric acid.}}{C^{16}H^{14}O^7} + H^2O = \underset{\text{Orsellinic acid.}}{2C^8H^8O^4} = 2CO^2 + \underset{\text{Orcin.}}{2C^7H^8O^2}.$$

A solution of lecanoric acid in aqueous *ammonia* acquires by exposure to the air a fine purple colour, due to the formation of orcein. In contact with *hypochlorite of calcium*, lecanoric acid immediately assumes a red tint, quickly changing to brown and yellow. The acid heated with *sulphuric acid*, is gradually converted into orcin. Boiling *nitric acid* converts it into oxalic acid. Boiling *acetic acid* dissolves it readily, and deposits it in small needles on cooling. By boiling with *alcohol*, it is converted into orsellate of ethyl. The same change is produced by passing hydrochloric acid gas into a solution of lecanoric acid in absolute alcohol, saturated at the boiling heat.

The ammoniacal solution of lecanoric acid forms white precipitates with basic *acetate of lead* and *nitrate of silver*: but the silver precipitate is quickly reduced. The alcoholic solution gradually produces, with an alcoholic solution of *acetate of copper*, a light apple-green precipitate. It does not precipitate the alcoholic solutions of neutral acetate of lead, mercuric chloride, chloride of gold or nitrate of silver. A few drops of *ferric chloride* impart to it a deep purple colour.

The lecanorates gradually decompose, especially when heated, yielding orsellinic acid, and ultimately orcin. The *barium-salt*, $C^{16}H^{12}BaO$, is obtained by dissolving the acid in cold baryta-water, passing carbonic acid into the liquid, and treating the precipitate with alcohol, which dissolves the lecanorate of barium, and deposits it in small stellate needles. According to Stenhouse's analysis, it contains 49·27 per cent. C, 3·81 H, and 19·49 baryta; the formula requires 49·87 C, 3·37 H, and 19·73 baryta. The *calcium-salt* is a gelatinous precipitate, slightly soluble in water and alcohol, obtained by mixing an ammoniacal solution of the acid with chloride of calcium. The

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lead-salt is precipitated, according to Rochleder and Heldt, on mixing the coholic solutions of lecanoric acid and acetate of lead; the precipitate thu probably consists for the most part of orsellinate.

LECANORIN. Syn. with LECANORIC ACID.

LECITHIN. Gobley's *Matière visqueuse.* (Gobley, J. Pharm. [3] 161; xi. 409; xii. 5; xvii. 401; xviii. 107; xix. 406; xxi. 241; xxx. 2 161.)—The eggs and milt or soft roe of the carp and herring, the yolk of po the brain of the domestic fowl, of man and of the sheep, venous blood, ox-bi fat of the garden-snail, contain, together with cholesterin, olein and m viscous substance which is decomposed by boiling with acidulated wate cerebrin, oleic acid, margaric acid and phosphoglyceric acid (ii. 891). Of thes Gobley regards the cerebrin as adventitious, the other three as resultin decomposition of a non-isolable substance, *lecithin*. The portion of pig's l in alcohol and not precipitable by ether contains, besides cholesterin and or a phosphoretted fat corresponding with Gobley's lecithin, and resolvable with baryta-water into phosphoglycerate of barium and insoluble b (Strecker, Ann. Ch. Pharm. cxxiii. 356). A constituent of yolk of egg, ear-wax, described by Kodweiss (Ann. Pharm. lix. 261), agrees also in pro the substance described by Gobley.

When carps' eggs are exhausted with ether or boiling alcohol, and the evaporated, there remains a reddish-yellow soft mass, which when redissolved alcohol, leaves a small quantity of oil. and separates again as a viscous mass It may also be obtained in the same manner, but less pure, from yolk of egg When the comminuted and partially dried milt of the carp is shaken up the ether takes up the greater part of the viscous matter, and the rest may be o repeated boiling with alcohol. On evaporating the alcoholic solution, trans viscous matter contained in the residue to ether by agitation therewith, and e the ether, the viscous matter is obtained free from the salts taken up by t which remain in the lower watery layer of liquid.

The viscous matter is colourless, or has merely a faint yellow or orange soft, neutral, and has for the most part the odour of the material from which prepared. It is frequently contaminated with earthy phosphates and It swells up when *heated*, chars without melting, gives off ammoniacal va leaves an acid carbonaceous residue containing phosphoric acid. When exp *air*, it does not turn acid, and afterwards yields the same decomposition-p that which has been prepared without exposure to the air. When shake *water*, it forms an emulsion which does not become sour or exhibit the p phosphoglyceric acid, even after 12 hours' boiling, but on boiling it with wat ing *sulphuric* or *hydrochloric acid*, oleic and margaric acids are formed, wh the surface as an oil, and phosphoglyceric acid, which remains dissolved in Addition of alcohol accelerates this decomposition, which, in viscous matter of egg, takes place at the mere heat of the water-bath, but in that derived f sources, not till after half an hour's actual boiling. The oxygen of the influence on the decomposition. Besides the products above mentioned, obtained cerebrin, and sometimes also cholesterin, olein and margarin, whic are regarded by Gobley as accidental admixtures.—Aqueous *alkalis* and *al bonates* at the boiling heat produce the same decomposition as the mineral aci the viscous matter of yolk of egg is shaken up with water containing potash in the water-bath, acetic acid separates oleic and margaric acids from it; with matter of the brain or from any other source, boiling with alcoholic potash is to effect the decomposition. Carbonate of potassium also does not deco viscous matter merely at the heat of the water-bath, but only on actual boi hours' boiling with *acetic* (lactic or tartaric) acid does not produce any deco 12 hours' boiling only an imperfect decomposition of the viscous matter; hours' boiling, it is completely decomposed, with formation of phosphoric glycerine. (Gobley.)

From the emulsion formed by *water*, which froths like soap (Gobley), it tated by common salt. (Kodweiss.)

The viscous matter dissolves sparingly in cold, easily in boiling *alcohol*, soluble in *ether*. (Gobley.)

LECONTITE. This name is given by W. H. Taylor (Sill. Am. J. 273) to an alkaline sulphate, found by Le Conte in the cavern of Las Pie Comayagua in Honduras, and probably formed from the excrements of b frequent the cavern in large numbers. The mineral, when freed from adheri matter, is colourless, permanent in the air, and has a saline, bitter forms prismatic crystals, which, according to Dana, are trimetric com

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Angle ∞P : ∞P = 103° 12′; ∞P̆2 : ∞P̆2 = 115°;
l axis = 127° 30′ to 128°. Hardness = 2 to 2·5.
it contains 12·94 per cent. $(NH^4)^2O$, 2·67 K^2O, 17·56
2·30 organic residue, and a trace of phosphoric acid,
$O^4.H^2O$.
agrees essentially with that assigned by Mitscherlich
salt $\left.\begin{matrix}NH^4\\Na\end{matrix}\right\}SO^4.2H^2O$. (Jahresber. 1858, p. 729.)

eral from Cape Blomidon, Nova Scotia, having the form
same formula, but with only one-third the amount of
169. Analysis by Hayes (Sill. Am. J. [2], xxv. 78):
l^2O^3, 11·48 CaO, 3·94 Na^2O, 0·14 FeO, 3·48 P^2O^5, and

SPHENE.

$C^{28}H^{30}O^{15}$? (E. Willigk, Ann. Ch. Pharm. lxxiv.
wartz, *ibid.* 366.)—A variety of tannic acid, obtained
vild rosemary (*Ledum palustre*). It is prepared by pre-
n of the leaves with water, after distilling off the alcohol;
neutral acetate of lead; dissolving the precipitate in
ain, precipitating the filtrate at the boiling heat with
osing the precipitate under water with sulphydric acid;
in a stream of carbonic anhydride (Rochleder and
l then remains as a reddish inodorous powder, easily
ıol. The aqueous solution is coloured dark-green by
ellow precipitates with acetate of lead and stannic

llow or red pulverulent substance, produced by boiling
ılphuric or hydrochloric acid. According to Willigk, it
efore produced from leditannic acid by elimination of
$4C^7H^6O^3$. It dissolves easily in alkalis, and when dis-
brown precipitate with an alcoholic solution of neutral
tillation, it yields an oil and crystals of pyrocatechin.

statements of different observers respecting this oil,
g the leaves of *Ledum palustre*, or the entire plant
exhibit considerable diversities. According to Willigk
consists for the most part of a hydrocarbon isomeric
an oxygenated oil, $C^{30}H^{126}O^5$. According to Grass-
i. 53), it consists of 1 pt. volatile oil and 2 pts. camphor
separated by slow distillation, the volatile oil passing
s colourless, slender, transparent prisms, which melt at
a stronger heat, diffusing a pungent odour, which pro-
ss. The camphor consists, according to Buchner
a hydrocarbon isomeric with oil of turpentine, and a
$C^{30}H^{26}O^2 = 5C^{10}H^{16}.3H^2O$. It is nearly insoluble in
chloric acid, less in acetic acid, and is quite insoluble
lves readily in alcohol and ether. (Buchner.)
. pr. Chem. lxxxii. 181), the oil obtained from the plant
w, has an acid reaction, smells like the flowering plant,
sily in alcohol and ether, and does not deposit any solid
o a very low temperature. When heated with strong
alkali, besides small quantities of acetic, butyric, and
aving the penetrative odour of the plant, and consisting
closely related to that of ericinone, $C^8H^8O^3$ (ii. 500),
s in the plant. The portion of the oil which does not
ectification in a stream of hydrogen, a portion boiling at
turpentine, while between 240° and 242° an oxygenated
position of ericinol, $C^{10}H^{16}O$.

found near Leeds in Yorkshire, containing, according to
ent. sulphate of calcium and 28·1 sulphate of barium.
anical mixture of the two. (Dana, ii. 507.)

plant yield 0·46, the stems 0·84 per cent. ash, contain-
son (Ann. Ch. Pharm. lxvii., Appendix to Part 3):

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	K^2O	Na^2O	CaO	MgO	SO^3	SiO^2	P^2O^5	Ferric phosphate.	NaCl
Bulb .	32·35	8·04	12·66	2·70	8·34	3·04	15·09	13·29	4·49
Stem .	13·98	14·43	25·10	trace	16·50	19·77	. .	10·06	trace

LEELITE. Syn. with HELLEFLINTA (p. 141).

LEGUMIN, or *Vegetable Casein,* was discovered by Einhof in 1805 called by him *végéto-animale* (N. allgem. J. d. Ch. v. A. Gehlen, vi. 126, found it in peas, beans, and lentils. A similar nitrogenised substance, extr sweet and bitter almonds and termed *amandin,* has been investigated b H. Vogel, Boullay, and others, who considered the substance in ques identical with animal casein. Braconnot, and afterwards Liebig, have the same result; they find, indeed, that legumin and casein are perfectl in composition and properties. Dumas and Cahours on the other hand, tained a substance containing less carbon and more nitrogen than casein sessing somewhat different properties. Their analyses agree very closely another, but it is highly probable that the substance analysed contained so body, perhaps arising from the partial decomposition of legumin. It is al likely that legumin prepared by the ordinary methods is not a homogeneous

Preparation.—Dumas and Cahours employ the following method for the p of legumin, the most advantageous source of which are peas or sweet almo bruised substance is digested for two or three hours with tepid water; the then crushed in a mortar so as to form a pulp; and to this is added abo weight of cold water. After the whole has been macerated for an hour, it on a cloth and pressed, and the liquid portion on standing deposits a certai of starch. The solution is now clarified by filtration, and acetic acid, di 8 or 10 times its weight of water, is gradually added. Immediately on the the acid, a perfectly white flocculent precipitate is formed, which may be easil on a filter and washed with water. Care must be taken to avoid an exces acid, in which legumin is readily soluble. The legumin is then washed wi dried, pulverised, and digested with ether, which removes all fatty mat product is again dried in vacuo at 140° (Gerhardt, *Traité,* iv. 491). Ha cannot well be substituted for the above substance, since they contain matter which renders the filtration and washing exceedingly tedious. to Löwenberg, the product, obtained as above, is a mixture of legumin an and after it has been washed with boiling water, contains a decompositi of legumin, mixed with albumin. The separation of these two substanc effected by dissolving the mixture in ammonia, evaporating off the excess o adding chloride of sodium, boiling, filtering, and precipitating the filtrate acid. The precipitate is washed first with cold water, then with boiling a ether. The infusion of peas and almonds also contains a third body, whic pitated by acetic acid; it is insoluble in excess of the acid, but soluble in The ammoniacal solution is partly precipitated by boiling with chloride of so evaporating the excess of alkali.

Rochleder purifies legumin, prepared by the first method, by treating it centrated potash, which readily dissolves the legumin, and leaves a floccule of another substance. The solution is allowed to stand, decanted, then fi precipitated by acetic acid. The well-washed precipitate is dissolved in filtered again, and reprecipitated by acetic acid.

Properties.—The solution of legumin does not coagulate by ebullition; evaporated, becomes covered with a pellicle, like milk (Liebig). Purified insoluble in cold water; with boiling water it yields a product richer in carb in water and insoluble in acetic acid, together with a less carbonised body, i water (Löwenberg). The body analysed by Dumas and Cahours had th properties:—When precipitated from a concentrated solution by weak ace always presented a nacreous and iridescent appearance; from a weak sol deposited in flakes. It is insoluble in cold alcohol and ether; also in bo and in weak boiling alcohol. It dissolves largely, however, in cold water, the liquid is heated almost to boiling, it coagulates, and gives a precipitate flakes very like coagulated albumin (Gerh. iv. 493). Gerhardt thinks that have experimented with the aqueous extract of legumin obtained directly from which probably contains that substance in combination with alkali, formin agulable solution like the alkaline albuminates. The fresh aqueous extract of the leguminosæ is always neutral; the legumin precipitated therefrom always reddens litmus, even after prolonged washing. When this solution itself, it coagulates in 24 hours, at a temperature of 15 or 20° C., yielding a precipitate like the coagulum of milk. The mother-liquor is decidedly appears to contain lactic acid. (Liebig.)

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In the following analyses the ash is deducted:—

	Dumas and Cahours.*		Rochleder.†			Rälling.‡	Löwenberg.‖
	Lentils.	*Sweet almonds.*	*Haricots.*			*Peas.*	*Peas.*
Carbon . .	50·46	50·93	54·0	54·3	53·9	50·68	53·9
Hydrogen .	6·65	6·70	7·5	7·4	7·3	6·74	7·2
Nitrogen . .	18·19	18·77	14·7	14·6	15·0	16·50	
Sulphur . .	. .	. .	. .	. .	. .	0·48	0·3
Oxygen . .							

Purified legumin sometimes contains as much as 7·1 per cent. ash (Rochleder). The ash is perfectly white, has an alkaline reaction, and contains a large quantity of potash, partly in combination with phosphoric acid. The insoluble portion of the ash is composed of phosphate of calcium and magnesium, as well as a little phosphate of iron. (Liebig.)

Völcker (Rep. Brit. Assoc. 1857, pr. 60; J. p. Chem. lxxv. 320) found in legumin prepared from peas and beans, the following percentage of ash, phosphorus, and sulphur:

Legumin.	Ash.	Phosphorus.	Sulphur.
From green peas	1·100	1·383	0·870
The same, precipitated with a small quantity of acetic acid . .		1·880	0·571
The same, precipitated with excess of acetic acid		2·180	0·851
From white peas	1·45	1·520	
From white French beans	0·71	1·780	0·590

Norton (Pharm. Centr. 1847, p. 466; 1848, p. 240) also found in legumin prepared from peas, sweet almonds, and oats, from 0·8 to 2·3 per cent. phosphorus. The large amount of phosphorus found by Völcker and Norton renders it probable that legumin contains, or is associated with, a compound of phosphoric acid, perhaps phosphoglyceric acid.

Decompositions.—When legumin is subjected to dry distillation, it swells, yields a yellowish distillate containing carbonate, sulphide, and acetate of ammonium, and leaves a residue of shining charcoal. (Braconnot.)

Legumin distilled with *acid chromate of potassium and dilute sulphuric acid* yields an acid liquid which smells of prussic acid and bitter almond oil, contains a considerable quantity of prussic acid, with a small quantity of formic acid, but does not give the reactions of the aldehydes with potash or with nitrate of silver. When rectified over mercuric oxide, the first portion of the distillate exhibited a more aromatic and ethereal odour than the original liquid; the second portion, which was covered with a thin layer of oil, contained benzoic acid (4 pts. to 1,000 of legumin) valerianic, butyric, propionic, acetic, caproic, and probably also caprylic acid (Fröhde, J. pr. Chem. lxxvii. 290). In a second series of experiments, Fröhde found among the products of oxidation of legumin, valeronitrile, acetonitrile (not distinctly recognised), and a third nitrile, probably propionitrile.

All *acids* coagulate the solution of legumin; the precipitates redissolve in excess of the acid.

When legumin is boiled with *dilute sulphuric acid*, leucine is formed. Dry legumin saturated with *concentrated sulphuric acid* dissolves slowly and forms a brown solution, but no glycocine is produced.

Concentrated *nitric acid* dissolves dry legumin, with evolution of nitrous fumes.

Dilute *hydrochloric acid* precipitates legumin like acetic acid. The concentrated acid dissolves it with the characteristic blue tint.

When gelatinous legumin is placed in contact with concentrated *acetic acid* it absorbs the acid, and swells, becoming semitransparent. The product is completely soluble in boiling water. A gummy residue of legumin, soluble in water, is obtained on evaporation. A solution of legumin is immediately precipitated by dilute acetic acid, and the precipitate is redissolved by an excess of the acid, forming a perfectly clear solution. This is reprecipitated by adding ammonia; the precipitate dissolves in an excess of the acid (Dumas and Cahours). Liebig found legumin insoluble in weak acetic acid; Löwenberg's legumin, which is insoluble in water, dissolves in an excess of acetic acid.

Solution of legumin is precipitated by tribasic *phosphoric acid*, also by *oxalic*, *tartaric*, *malic*, and *citric acids*; the precipitates are readily soluble in excess of acid. Legumin is dissolved in the cold by *potash*, *soda*, and *ammonia*. Heated with fixed alkali, it evolves ammonia, and sulphide of ammonium is formed in the solution.

* The carbon and nitrogen in the other analyses of MM. Dumas and Cahours fall between these two analyses.

† Previously purified by Rochleder's method.

‡ The substance was redissolved in ammonia, precipitated by acetic acid, and exhausted by boiling alcohol and ether.

‖ Purified by Löwenberg's process.

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Baryta and *lime* form insoluble compounds with legumin, as with casein. Li solution of legumin precipitates many earthy and metallic salts, but does no tate sulphate of magnesium, or the acetate, or other salts of calcium in the applying a slight heat, the liquid rapidly coagulates. Braconnot attributes th ing of vegetables cooked in selenitic waters to the formation of these lime-co

A concentrated solution of legumin, to which rennet has been added, does to coagulate for several hours; after 24 hours all the legumin is precipitat coagulation does not appear from this to be due to the free acid contained in t (Dumas and Cahours). Putrefying legumin acts as a powerful ferment.

Dry beans, peas, lentils, &c., contain, on an average, about 25 per cent. genised matter (legumin, albumin, &c.), and are the most nutritive of vegeta the same time, they are deficient in starch and fat. They are not genera wholesome food in large quantity, except for men enjoying robust health and in severe labour. Legumin appears to be much more indigestible than insolub as casein is far more indigestible than the fibrin of meat. C

LEHMANNITE. Native chromate of lead (i. 934).

LEHRBACHITE. Selenide of mercury and lead from Tilkerode, near L probably a mechanical mixture of the two selenides, inasmuch as specimens ferent parts of the same vein exhibits very different proportions of lead and (see p. 558).

LEHUNTITE. Syn. with NATROLITE.

LEIDENFROST'S PHENOMENON. This term is sometimes appli spheroïdal state of liquids (p. 88), first observed by Leidenfrost.

LEMNA. *Duckweed.*—Plants of this genus are very rich in inorganic su and have accordingly been recommended for use as manure. In a specimen *minor* growing in the river Eure, in France, Hervé Mangon (Instit. 186 found:

Combustible matter (without nitrogen).	Nitrogen.	Silica.	Lime.	Phosphoric acid.	Other mineral constituents.
61·1	3·6	6·7	8·2	1·1	19·3 =

Liebig (Ann. Ch. Pharm. cv. 109) obtained from *Lemna trisulca* growing in 16·6 per cent. ash, and from a litre of the surrounding water 0·415 grm. residue. 100 pts. of the slightly ignited plant-ash, *a*, and of the saline resid water, *b*, contained:

	CaO	MgO	NaCl	KCl	K^2O	Na^2O	Fe^2O^3*	P^2O^5	SO^3
a.	16·82	5·08	5·90	1·45	13·16	. .	7·36	8·73	6·09
b.	35·00	12·26	10·10	. .	3·97	0·47	0·72	2·62	8·27

LEMNIAN EARTH. *Sphragide.*—The Λημνία σφραγίς of the Gr yellowish-grey earth or clay frequently marbled with rusty spots. Dull. fine earthy. Meagre to the touch. Adheres slightly to the tongue. When in water it falls to pieces, with disengagement of air-bubbles. Its con are, 66 silica, 14·5 alumina, 0·25 magnesia, 0·25 lime, 3·5 soda, 6 oxide of water (Klaproth). It has hitherto been found only in the Island of S (ancient Lemnos). It is reckoned a medicine in Turkey; and is dug up onl year, with religious solemnities, cut into spindle-shaped pieces, and stampe seal. In ancient times it was esteemed an antidote to poison and the plague.

LEMON. See CITRUS (i. 1003).

LENTIL. *Ervum Lens.* The air-dried seed of this leguminous plant according to Krocken (Ann. Ch. Pharm. lviii. 224), from 34 to 35 per cent. Horsford (*ibid.* 199) found in 100 pts. of the seed, 30·4 pts. of non-azotised to 2·6 ash and 13·0 water.

Poggiale (J. Pharm. [3]. xxx. 180, 255), and Fresenius found in 10 air-dried lentils, the following constituents:

Starch.	Gum.	Sugar.	Legumin.	Fat.	Cellulose, Pectin, &c.	Ash.	Water.	
44		. .	29·0	1·5	7·7	2·4	15·4	Pogg
35·5	7·0	1·5	25·0	2·5	12·0	2·3	14·0	Fres

Levi found in lentil-seeds from Worms 2·06 per cent. ash of the compositi below.

The straw of lentils contains 0·01 per cent. nitrogen (Boussingault); dried straw contains 27 per cent. water and 34 per cent. substances soluble i alkaline ley, 57 per cent. woody fibre, and 3·9 per cent. ash, having the fo composition:

* With traces of alumina.

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Composition of Lentil-ash.

	Seed.	Straw.		Seed.	Straw.
Potash	34·6	10·8	Silica	1·3	17·6
Soda	9·5		Phosphoric acid	36·2	12·3
Lime	6·3	52·3	Sulphuric acid		1·0
Oxide of manganese	2·5	3·0	Chloride of sodium	7·6	2·1
Ferric oxide	2·0	0·9			

According to Schwarz, a hectare of ground yields about 1,360 kilogrammes of seed and 3,700 kilogrammes of straw; the former, therefore, containing 30, the latter 144, and the whole, 174 kilogrammes of mineral constituents (Handb. d. Chem. ii. [3] 832).

LENZINITE. A variety of kaolin from the pegmatite of La Vilate near Chanteloupe (Haute Vienne), of a clear brown colour, tender, but not plastic. Before the blowpipe it becomes reddish, but does not fuse. It is decomposed by hot sulphuric acid. Contains, according to Salvétat (Ann. Ch. Phys. [3] xxxi. 102), 36·36 per cent. silica, 36·00 alumina, 1·95 ferric oxide, and 21·50 water (agreeing nearly with the formula $2Al^2O^3.3SiO^2.3H^2O$), besides 0·18 magnesia, 0·50 alkalis, 2·0 gelatinous silica, and 1·64 quartz (=101·62).

LEONHARDITE. A hydrated silicate of calcium and aluminium, occurring at Schemnitz in Hungary, and at Copper Falls, Lake Superior, in monoclinic crystals, in which $\infty P : \infty P = 83° 30'$ and $96° 30'$; $oP : \infty P = 114°$. Cleavage parallel to ∞P, very perfect; basal imperfect. Also columnar and granular. Hardness = 3 to 3·5. Specific gravity = 2·25. Lustre on cleavage-faces pearly; elsewhere vitreous. Colour white, sometimes yellowish, seldom brownish. Subtranslucent. It usually whitens on exposure, like laumontite; but the variety from Lake Superior does not. Before the blowpipe it exfoliates, froths, and easily melts to an enamel. It dissolves in acids.

Leonhardite from Schemnitz has been analysed by Delffs and v. Babo (Pogg. Ann. lix. 336, 339), that from Copper Falls by Barnes (Sill. Am. J. [2] xv. 440):

	Schemnitz.		Copper Falls.
Silica	54·92	55·00	55·50
Alumina	22·49	24·36	21·69
Lime	9·05	10·50	10·56
Water	13·54	12·30	11·93
	100·00	102·16	99·68

The analyses do not agree well together. The first analysis of the Hungarian mineral agrees approximately with the formula $(3CaO.4SiO^2).4(Al^2O^3.3SiO^2) + 15H^2O$, which, however, is improbable; that of the American mineral may be represented by the much simpler formula $(CaO.SiO^2).(Al^2O^3.3SiO^2) + 3H^2O$, or $2CaAl'''Si^2O^8.3H^2O$, which is that of a metasilicate, and differs from the formula of laumontite (p. 472) only in the amount of water. According to Brooke and Miller, leonhardite agrees in form also with laumontite. Delffs found in the mineral 13·55 to 13·81 per cent. water; it gave off 11·64 per cent. at 100°. According to Kenngott, leonhardite is identical with caporcianite. (Dana, ii. 308; Rammelsberg, *Mineralchemie*, p. 806.)

LEOPARDITE. A spotted felspathic rock, occurring at Charlotte, Mecklenburgh County, and in the Steele Mine, Montgomery County, North Carolina, and recognised by Genth (Sill. Am. J. [2] xxxiii. 197), as a true porphyry, spotted with iron- and manganese-compounds. The crypto-crystalline felspathic base is interspersed with small crystals of orthoclase and quartz. Analysis gave:

SiO^2	Al^2O^3	Fe^2O^3	MgO	CaO	Na^2O	K^2O	Loss by ignition.
75·92	14·47	0·88	0·09	0·02	4·98	4·01	0·64 = 100·00

agreeing very nearly with the composition of Bunsen's normal trachytic substance.

LEPAMINE. A volatile base containing the elements of 1 at. diamylamine and 1 at. lepidine; $C^{10}H^{23}N.C^{10}H^9N = C^{20}H^{32}N^2$, produced by the action of iodide of amyl on lepidine (p. 573).

LEPARGYLIC ACID. Syn. with Anchoic acid (i. 289). Arppe has lately shown (Ann. Ch. Pharm. cxxiv. 86) that Laurent's *Azelaic acid* (i. 477) has the same composition as lepargylic or anchoic acid: it appears, however, to differ so much from the latter in melting point, solubility, and the properties of some of its salts, that the two acids can scarcely be regarded as identical (which is Arppe's view), but only as isomeric.

Azelaic acid is most easily obtained by heating castor-oil with 2 pts. of nitric acid,

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of specific gravity 1·2—1·3, added by small portions, continuing the operati hours, then separating the acid liquid from the remaining oil, adding fresh continuing the oxidation for another day. The acid liquid is then to be separ the oil and added to the former portion, the whole evaporated, with addition and freed from oil, which then separates, by means of a tap-funnel. The solution duly concentrated yields a white granular mass, which, when freed f acid by washing with cold and recrystallisation from warm water, and from c soluble acids by melting the crystals, pulverising the fused mass, and tr powder with water, leaves a mixture of azelaic and suberic acids; and on tr residue with cold ether, the azelaic acid is dissolved, while the suberic aci behind. The ethereal solution is evaporated, the residue is dissolved in hot the solution, freed from any oil that may still remain, is evaporated to the cr point.—Azelaic acid is also obtained in a similar manner, together with sev acids, from almond-oil, spermaceti, and oleic acid (Arppe, Ann. Ch. Ph 288; Jahresber. 1861, p. 357).

Azelaic acid, prepared as above, has the composition $C^9H^{16}O^4$. It cryst cooling from a moderately concentrated aqueous solution, sometimes in larg sometimes in long flattened needles several inches long; the crystals are tr and colourless, with vitreous lustre, but of no determinate form. From a v solution, it separates in smaller laminæ, which under the microscope exhil forms, viz. oblique rhombic prisms with acute angles of about 22°, square t thin flattened prisms. It dissolves in 700 pts. water at 15° (lepargylic acid, according to Buckton, in 217·4 pts. at 18°); it is more soluble in still more in alcohol. It melts at 106° (lepargylic acid at 114—116°, Buck tially at 115°, completely at 124°, Wirz); and volatilises with partial decomp higher temperatures; the vapours excite coughing, but not so strongly a acid. Heated with caustic baryta, it is resolved into carbonic anhydride an of heptyl, C^7H^{16}, together with small quantities of other hydrocarbons; $C^9H^{18}O^4 = 2CO^2 + C^7H^{16}$. (R. S. Dale, Chem. Soc. J. xvii. 261.)

The azelaates of the alkali- and alkaline-earth-metals are soluble in calcium-salt being the least soluble; those of the heavy metals are insolub are all decomposed by dilute *nitric acid*, with separation of crystalline az The neutral salts form with *chloride of calcium* a copious crystalline precip *ferric chloride* a brick-red, and with *cupric sulphate* a blue-green precipitate.

Barium-salts.—The *acid salt*, $C^{18}H^{30}Ba''O^8$, is obtained by neutralising a h of the acid with carbonate of barium. [Buckton did not succeed in preparin anchoate of barium.]—A warm concentrated solution of the acid neutral hydrate of barium yields a granular precipitate of the salt $2C^9H^{14}Ba''O^4.C^1$ which may be crystallised from water, but when washed with hot water is into the *neutral salt*, $C^9H^{14}Ba''O^4$.

The *calcium-salt*, $C^9H^{14}Ca''O^4$, is very sparingly soluble. The *copper-salt*, C^9 is a blue-green precipitate; the *lead-salt*, $C^9H^{14}Pb''O^4$, a white precipit *magnesium-salt*, $C^9H^{14}Mg''O^4.3H^2O$, is efflorescent, and separates from solutio water by evaporation in crystalline crusts. The *manganese-salt*, $C^9H^{14}M$ white fusible precipitate; the *nickel-salt*, an apple-green crystalline precip *silver-salt*, $C^9H^{14}Ag^2O^4$, a white powder.—The *strontium-salt*, $C^9H^{14}Sr''O^4.2$ rates by evaporation from its warm aqueous solution in crystalline crusts, w dried in the exsiccator, give off half their water, leaving granular crystals $C^9H^{14}Sr''O^4.H^2O$. (Arppe.)

LEPIDINE. $C^{10}H^9N$. (Gr. Williams, Edinb. Phil. Trans. xxi. [3] xiv. 103.)—A volatile organic base homologous with chinoline, and obtained with that base, and several others of the series, by distilling quinine or c with water and hydrate of potassium (i. 809). The bases are first sep fractional distillation,—the portion which distils above 199°, especially tha 216° and 243°, consisting of chinoline and lepidine, the latter being found chi portion boiling above 270°,—and the separation is completed by fractiona lisation of their platinum-salts.

A base isomeric, and originally supposed to be identical, with lepidine is in coal-tar oil, and may be separated by collecting and rectifying the port distils between 250° and 267°, and completing the purification by fractional sation of the platinum-salt as above. This base, now called iridoline, is dist from lepidine by its lower boiling point, by certain differences in the ch its salts, some of which crystallise less easily than the corresponding salts of and in particular by the reaction of its amyl-derivative with ammonia (p. 57

Lepidine is an oily base resembling chinoline, of specific gravity 1·07 boiling between 266° and 271° (iridoline boils between 252° and 257°). density, obs. = 5·14, calc. = 4·96.

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Lepidine is somewhat decomposed by boiling, yielding pyrrhol and carbonate of ammonia. By *iodide of methyl, ethyl* and *amyl*, it is converted into iodide of methyl-, ethyl- and amyl-lepidyl-ammonium (p. 573).

Both lepidine and iridoline form crystallisable salts; the iridoline-salts smell of naphthalene. The *hydrochlorates* of both bases, $C^{10}H^9N.HCl$, form small colourless needles, which do not melt at 100°. They form, with *chloride of cadmium*, crystalline double salts containing $C^{10}H^9N.HCl.CdCl^2$; and with *tetrachloride of platinum*, the salt $2(C^{10}H^9N.HCl).PtCl^4$, which is insoluble in alcohol. The platinum-salt of iridoline crystallises less readily than that of lepidine.

The *nitrates*, $C^{10}H^7N.NO^3$, form hard prisms which are permanent in the air, and do not melt at 100°.

Acid chromate of lepidine, $2C^{10}H^9N.H^2O.2CrO^3$, crystallises in long golden-yellow needles which decompose at 100° when moist, but not when dry, and leave chromic oxide when ignited.—*Acid chromate of iridoline* is an oily compound which does not crystallise.

Derivatives of Lepidine.

Amyl-lepidine. $C^{15}H^{19}N = N\left\{\begin{matrix}C^5H^{11}\\C^{10}H^7\\H\end{matrix}\right.$.—The hydriodate of this base, or iodide of amyl-lepidyl-ammonium, $C^{15}H^{20}NI = N[(C^5H^{11})(C^{10}H^7)H^2]I$, is obtained by heating lepidine with iodide of amyl, in small crystals, slightly soluble in water. This iodide treated with potash or ammonia is converted into a splendid blue compound (Gr. Williams), called iodide of pelamine; the reaction is,

$$\underset{\text{Iodide of amyl-lepidyl-ammonium.}}{2C^{15}H^{20}NI} + KHO = \underset{\text{Iodide of pelamine.}}{C^{30}H^{38}N^2I} + KI + H^2O.$$

When treated with moist oxide of silver, it yields the base, and from this the other salts of pelamine may be obtained (see PELAMINE). The crude distillate from cinchonine treated with iodide of amyl and potash yields a similar blue compound (known commercially as *chinoline blue* or *cyanine* (i. 873), which consists mainly of iodide of pelamine, together with a small quantity of the homologous compound $C^{29}H^{36}N^2I$, derived in a similar manner from chinoline. (Hofmann, Compt. rend. lv. 849; Proc. Roy. Soc. xii. 410).

Diamyline-lepidine or **Lepamine.** $C^{20}H^{27}N^2$ = $C^{10}H^{25}N.C^{10}H^9N$, or perhaps $\left.\begin{matrix}(C^5H^{11})^2\\(C^{10}H^9)''\\H^2\end{matrix}\right\}N^2$. (Gr. Williams, Chem. Soc. J. xvi. 375.)—When lepidine is cohobated with iodide of amyl, a brown syrupy liquid is obtained, which solidifies to a mass of crystals on cooling. On repeatedly boiling this mass with water, the greater part dissolves, yielding a solution of iodide of amyl-lepidyl-ammonium. A considerable portion however remains undissolved, and this portion, if subjected to prolonged ebullition in a retort with caustic alkalis, decomposes, yielding a distillate consisting of water and an oil. The latter dissolves for the most part in hydrochloric acid, and the solution, evaporated to a moderate bulk, forms two layers, the upper, which appears like a colourless oil, solidifying on cooling to a mass resembling paraffin, while the lower is merely a saturated aqueous solution of the same substance. The paraffin-like hydrochlorate, treated with alkalis and distilled, yields diamyline-lepidine as a volatile base, which may be dried with sticks of potash, and rendered nearly colourless by rectification. It has a fragrant odour, and when perfectly dry distils at about 175°. Vapour-density, obs. = 10·40; calc. = 10·38.

Hydrochlorate of lepamine, $C^{20}H^{27}N^2.2HCl$, melts below 100°, is sparingly soluble in water, and must be dried in a vacuum before being heated over the water-bath.

Chloroplatinate.—On adding an excess of strong hydrochloric acid to a solution of the base, so as to obtain the hydrochlorate as an oil floating on the surface, and then a considerable excess of tetrachloride of platinum, an adhesive yellow mass is formed, which may be washed by agitation with cold water, dried over oil of vitriol for a day or two and then over the water-bath. It is perfectly soluble in alcohol, and has the composition, $2(C^{20}H^{27}N^2.2HCl).PtCl^4$.

Gold-salt.—On adding trichloride of gold to a solution of the hydrochlorate, a chocolate-coloured precipitate is formed, which quickly changes to bright green; it is soluble in alcohol, forming a green solution.

Lepamine dissolved in strong *nitric acid* yields a red solution, from which on dilution, a red oil separates, probably a nitro-compound.

By heating lepamine with *iodide of ethyl* in a sealed tube, a syrupy liquid is obtained which when distilled with potash, yields a volatile oily base, probably ethyl-lepamine.

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It dissolves readily in hydrochloric acid, forming a salt which is much more to crystallise than hydrochlorate of lepamine.

Ethyl-lepidine. $C^{12}H^{13}N = C^{10}H^{8}(C^{2}H^{5})N$.—The hydriodate of this *iodide of ethyl-lepidyl-ammonium*, $[(C^{2}H^{5})(C^{10}H^{7})H^{2}]NI$, is obtained by hea dine with iodide of ethyl, in brown needles, which after recrystallisation, beautiful canary-yellow colour, becoming transiently blood-red at 100°. Tre moist oxide of silver, it yields the corresponding hydrate, which when tre hydrochloric acid and tetrachloride of platinum, yields the platinum-salt, 2C $PtCl^{4}$, soft at first, but soon becoming crystalline.

Methyl-lepidine. $C^{11}H^{11}N = C^{10}H^{8}(CH^{3})N$.—The hydriodate, or iodide o *lepidyl-ammonium*, $C^{11}H^{12}NI$, is obtained in crystals by heating lepidine with methyl.

LEPIDOCROCITE. *Needle Iron ore.*—A hydrated ferric oxide of composition as göthite, $Fe^{2}O^{3}.H^{2}O$ (ii. 940), occurring at Spring Mills, Mo County, Pennsylvania, in minute radiating crystals or granular scales, and aggregations, imbedded in fibrous red oxide of iron, and in nodules of chalce

LEPIDOLITE. Lithia-mica, found at Rogena and Iglau in Moravi island of Utön, Sweden, and in other localities. (See MICA.)

LEPIDOMELANE. A variety of mica, so called from its scaly struc black colour (λεπίς and μέλας), consisting, according to Soltmann's analys Ann. l. 664) of 37·40 silica, 11·60 alumina, 27·66 ferric oxide, 12·43 ferro 9·20 potash, 0·26 lime and magnesia, and 0·60 water, corresponding with the (FeO; $K^{2}O$).($Al^{2}O^{3}$; $Fe^{2}O^{3}$).$2SiO^{2}$, which is reducible to that of an orth $\left.\begin{matrix}M'\\R'''\end{matrix}\right\}SiO^{4}$.

The mineral forms crude masses of granular scaly structure, consisting o scales, sometimes exhibiting the form of six-sided tables; according to Wöhl completely decomposed by hot hydrochloric or nitric acid, the silica separa crystalline scales like those of the mineral. It is found only in one locality in probably at Persberg, Wermland.

LEPOLITE. See ANORTHITE (i. 308).

LEPTYNITE. *Granulite* or *Eurite.* A granular compound of felspar with sometimes containing garnet.

LEUCANILINE. $C^{20}H^{21}N^{3}$. (A. W. Hofmann, Proc. Roy. Soc. xii. 2; ber. 1862, p. 34.)—A base produced by the action of reducing agents on ros and related to it in the same manner as indigo-white to indigo-blue:

$$\underset{\text{Rosaniline.}}{C^{20}H^{19}N^{3}} + H^{2} = \underset{\text{Leucaniline.}}{C^{20}H^{21}N^{3}}.$$

It may be obtained by leaving hydrochlorate of rosaniline in contact with metal or more easily by digesting a salt of rosaniline (or commercial fuchsine or magen sulphide of ammonium. A yellow resinous mass is then formed, which is to l pulverised, washed with water and dissolved in dilute hydrochloric acid. The forms with concentrated hydrochloric acid, a copious, crystalline, brown or precipitate, of impure hydrochlorate of leucaniline, which may be purified by r solution in dilute, and precipitation by concentrated hydrochloric acid. It cry from boiling dilute hydrochloric acid in very small rectangular plates, wh obtained quite pure by recrystallisation from water, or by precipitation of the a solution with ether.

Leucaniline is precipitated from the solution of the hydrochlorate as a white acquiring a faint rose tint on exposure to the air. It is nearly insoluble i sparingly soluble in boiling *water*, whence it separates in small crystals, slightly in *ether*, easily in *alcohol*. It turns red when heated, and melts at 100° to a d transparent liquid, which solidifies to a lighter-coloured mass on cooling. By o agents, such as peroxide of barium, ferric chloride, and especially chromate of pot it is easily converted into rosaniline. It unites with sulphide of carbon, chloride zoyl, and several other bodies, forming compounds which have not yet been exa

The salts of leucaniline crystallise well, especially the sulphate; they are all in water, and are precipitated by acids. The *hydrochlorate*, $C^{20}H^{21}N^{3}.3HCl.H^{2}$ up its water only when heated for a long time in a stream of hydrogen. On its solution with excess of leucaniline, the latter separates out in splendid without forming a less acid salt. The *chloroplatinate*, $2(C^{20}H^{21}N^{3}.3HCl).3PtCl$ is sparingly soluble in cold water, decomposible by boiling water, and gives water with difficulty, even when heated above 100°. The *nitrate*, $C^{20}H^{21}N^{3}.3HN$

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forms white needles soluble in water and in alcohol, but not in ether, only sparingly in nitric acid, and decomposing at 100°.

Triphenyl-leucaniline. $C^{39}H^{33}(C^6H^5)^3N^3$.—Obtained by the action of reducing agents on triphenyl-rosaniline. The blue solution of the hydrochlorate of this base is decolorised by zinc and hydrochloric acid, and the clear liquid treated with water yields a precipitate which may be purified by solution in ether. The same compound is obtained as a brittle, non-basic resin, by the action of sulphide of ammonium on hydrochlorate of triphenyl-rosaniline. It is anhydrous, and when treated with oxidising agents, is reconverted into triphenyl-rosaniline. (Hofmann, Compt. rend. lvii. 25.)

LEUCAZOLITMIN. See LITMUS.

LEUCHTENBERGITE. A variety of chlorite (i. 914) from Slatoust in the Ural. Breithaupt regards it as an altered chlorite. Komonen found in it only 8·62 per cent. water instead of 12·62, the percentage in normal chlorite. Kenngott regards it as a distinct species.

LEUCIC ACID. $C^6H^{12}O^3$. (Strecker, Ann. Ch. Pharm. lxviii. 55; Gössman, *ibid.* xci. 135; Waage, *ibid.* cxviii. 295; Thudichum, Chem. Soc. Qu. J. p. xiv. 307; Frankland, Proc. Roy. Soc. xii. 396; Frankland and Duppa, *ibid.* xiii. 140.)—An acid, homologous with lactic acid, produced:—1. From *leucine*.—*α*. When nitric oxide gas is passed through a solution of leucine in strong nitric acid, nitrogen is evolved and leucic acid is formed (Strecker). The same reaction takes place when nitrous acid is passed through a solution of leucine in warm water (Thudichum), or water slightly acidulated with nitric acid (Waage):

$$\underset{\text{Leucine.}}{C^6H^{13}NO^2} + \underset{\text{Nitrous acid}}{HNO^2} = \underset{\text{Leucic acid.}}{C^6H^{12}O^3} + N^2 + H^2O.$$

Cahours had previously observed (Compt. rend. xxvii. 368) that a peculiar acid is formed when an aqueous solution of leucine is left to itself.—*β*. When chlorine gas not in excess is cautiously passed through a solution of leucine in caustic soda, leucic acid is formed and may be separated from the mixture in the same manner as benzoglycollic acid (i. 548) from hippuric acid. (Gössmann.)

2. From *oxalate of ethyl*, by the action of zinc-ethyl. The direct product of this action is probably zincoleucic ether, a body not isolated, thus [zn = 32·5 = ½ zn]:

$$\underset{\text{Oxalate of ethyl.}}{C^6H^{10}O^4} + \underset{\text{Zinc-ethyl.}}{\begin{cases} znC^2H^5 \\ znC^2H^5 \end{cases}} = \underset{\text{Zincoleucic ether.}}{C^6H^{10}(znC^2H^5)O^3} + \underset{\text{Ethylate of zinc.}}{zn(C^2H^5)O}.$$

The zincoleucic ether is converted by the action of water into leucic ether:

$$\underset{\text{Zincoleucic ether.}}{C^6H^{10}zn(C^2H^5)O^3} + H^2O = \underset{\text{Leucic ether.}}{C^6H^{11}(C^2H^5)O^3} + znHO;$$

and from this, the barium-salt, and thence the acid itself, is easily obtained. (Frankland.)

Preparation.—1. Pure leucine is dissolved in boiling water slightly acidulated with nitric acid; nitrous acid gas is passed through the warm solution as long as nitrogen continues to escape; the liquid, which turns brown and gradually deposits brown flakes, is left to cool, then agitated several times with ether; and the ethereal extracts are evaporated. The residue is a brown oily liquid not miscible with water, which gradually solidifies to a radio-crystalline mass. The aqueous solution, freed from leucic acid by repeated agitation with ether, left on evaporation a considerable quantity of nitro-leucic acid.—To purify the crude leucic acid thus obtained, it is dissolved in a large quantity of water (a smaller quantity dissolves it but imperfectly); the boiling liquid is mixed with an aqueous solution of acetate of zinc; and the precipitated leucate of zinc is washed on the filter with water (which dissolves but a small quantity of it), purified by recrystallisation from alcohol, then suspended in water, and decomposed by sulphuretted hydrogen. The filtered solution is but very slightly coloured, and when evaporated to a syrup and left to stand, yields leucic acid in colourless needles. If, on the other hand, the zinc-salt be suspended in alcohol and decomposed by sulphuretted hydrogen, the acid is obtained in hard, brittle prisms. (Waage.)

2. Thudichum passes nitrous acid gas through a warm aqueous solution of leucine; evaporates, with addition of leucine, to neutralise the free nitric acid, and prevent it from oxidising the leucic acid; agitates the syrupy residue with ether (or extracts the leucic acid from the aqueous solution by agitation with ether, without previous evaporation; in which case, however, the treatment with ether must be repeated a great number of times)—and purifies the crude leucic acid from adhering brown oil, either by solution in cold water, filtration and recrystallisation,—or by strongly pressing the coloured crystals between bibulous paper—or by precipitating the aqueous solution

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with acetate of lead, decomposing the washed precipitate with sulphurette and evaporating the filtrate either over the water-bath at a very moder over sulphuric acid.

3. Oxalic ether is mixed with its own weight of zinc-ethyl, in a rounded by cold water, to prevent rise of temperature and the consequent o a secondary reaction, attended with the evolution of large quantities of et hydride of ethyl; towards the end, however, the reaction requires to be ass application of a gentle heat. The mixture, which generally remains fluid, is cooling, with its own volume of water (whereupon torrents of hydride of et from excess of zinc-ethyl, are evolved), and subsequently distilled in a Weak alcohol containing an ethereal oil in solution then passes over, an quantity of the oil may be obtained by adding water to the residue in the continuing the distillation on a sand-bath. The oil is precipitated from t distillate by water, added to that which floats on the surface of the water then dried over chloride of calcium, and rectified. The principal portion, w between 174° and 176°, consists of leucic ether. (Frankland.)

The process may be greatly simplified, and a larger product obtained, by the zinc-ethyl during the reaction, namely by heating a mixture of amalga iodide of ethyl, and oxalic ether to the necessary temperature. The operat considered complete when the mixture has solidified to a resinous-looking this, when treated with water as above, and distilled, yields a considerable leucic ether. (Frankland and Duppa.)

The leucic ether heated with hydrate of barium, is converted into leucate and this when decomposed by dilute sulphuric acid, yields a solution of leu

Properties.—Leucic acid forms colourless needles (Strecker); needl brittle prisms, of the trimetric or monoclinic system, according to the mod ration (Waage); radiary group of needles, having a mother-of-pearl lu beautiful variety of concentric markings, like those of some kinds of (Thudichum); it is heavier than water, and cuts like hard soap, almost acid (Thudichum); it has an acid taste, and reddens litmus (Thudichu taste, and strong acid reaction (Waage). It melts below 100° and solidifie (Thudichum); melts at 73°, and sometimes solidifies at a few degree melting point, sometimes remains liquid even when cooled to 0° (Waa easily soluble in *water* and in *alcohol*, soluble also in *ether*.

Decompositions.—1. Leucic acid volatilises at 100°, apparently without tion. When it is placed on a watch-glass and heated over the water-bath, the glass become fringed with crystals of the sublimed acid, which dissol water, leaving, however, a few flocks, probably consisting of the anhydride. which remains in the middle of the watch-glass is syrupy, dissolves in after prolonged boiling, but is easily soluble in alcohol and ether; it probab sists of leucic anhydride (Waage). The acid heated for some time in the continually gives off acid-smelling vapours, and does not afterwards solidify but remains in the form of an uncrystallisable, dark-brown, smeary syrup dride, which has a very disagreeable odour, remains unchanged, even wh oil of vitriol for weeks, and is nearly insoluble in water, separating from i and sinking to the bottom. A small quantity of this insoluble compound formed, when the aqueous solution, even if dilute, is heated to the boili evaporated (Thudichum). Leucic acid may be boiled with water witho sition, and traces only of it distil off with the water (Frankland).—2. strongly heated in the *air*, gives off thick fumes and blackens, then takes fi with a yellow smoky flame, leaving a small quantity of charcoal, which is easily consumed. (Thudichum.)

Leucates. Leucic acid forms crystallisable salts, the composition which may be represented by the formulæ, $M'C^6H^{11}O^3$ and $M''(C^6H^{11}O^3)^2$ analogous in composition to the lactates, the acid being diatomic and mon acid silver-salt has, however, been obtained, having the composition $C^6H^{11}Ag$ The leucates are for the most part obtained by boiling the aqueous sol acid with the corresponding carbonates (Thudichum). They are less the lactates in water, more soluble in alcohol. (Waage.)

Leucate of Ammonium.—The acid slightly supersaturated with a evaporated, leaves a thick homogeneous residue, in which no trace of crysta be observed, even after drying for several weeks over oil of vitriol. (Th

Leucate of Barium, $Ba''(C^6H^{11}O^2)^2$.—Obtained by digesting the with carbonate of barium, or by heating leucic ether with hydrate of bariu the excess of baryta by carbonic acid, filtering and evaporating (F

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Waage, Thudichum). It dissolves with moderate facility in warm water and dilute alcohol, and separates from boiling alcohol in beautiful colourless, silky, laminar crystals, which, like most leucates, retain something of the appearance of leucine. (Waage.)

Leucate of Calcium, $Ca''(C^6H^{11}O^3)^2$.—An aqueous solution of the acid neutralised with chalk or milk of lime, and left to evaporate, yields the calcium-salt in fine needles, easily soluble in water and in alcohol.

Leucate of Cobalt, $Co''(C^6H^{11}O^3)^2$.—The dilute aqueous acid boiled with excess of carbonate of cobalt, then filtered and evaporated, deposits light crusts of a pink colour while moist, but of a very pale rose-colour or almost white when dry. The salt is but sparingly soluble in cold water, and not much more soluble at the boiling heat. It crystallises in needles, which, under the microscope, appear to be arranged in globular masses. (Thudichum.)

Leucate of Copper.—When a dilute aqueous solution of leucic acid is treated with a dilute solution of ammonio-sulphate of copper, the colour of the copper-salt changes to light-green. On boiling the liquid, it becomes paler, and on cooling deposits light green granules of leucate of copper. Under high powers of the microscope, these granules appear as balls, formed by a radiary arrangement of needles (Thudichum). A solution of leucic acid mixed with acetate of copper, forms a green flocculent precipitate, very sparingly soluble in water, even at the boiling heat, but easily crystallised from boiling alcohol, from which it separates in very beautiful light blue, shining, bulky scales, which do not undergo any diminution in weight at 100°. (Waage.)

Leucate of Lead.—On adding acetate of lead to a solution of leucic acid or a leucate, a copious white flaky precipitate is formed, which on boiling dissolves almost entirely in the liquid. Any portion remaining undissolved melts into a white mass, which is soft like resin while warm, but becomes brittle and hard on cooling. This substance is insoluble in water and alcohol, even on boiling, and seems to be a basic salt.

If the solution of lead is added to a boiling solution of the acid, no precipitate ensues, acid vapours are evolved, and the liquid becomes milky on cooling. In a short time, it deposits the lead-salt as a light, granular, white mass, which, under the microscope, appears to be made up of a multitude of strongly refracting spherical masses, of the size of human blood-corpuscles. This salt is more easily soluble in an excess of the acetate than in water. It is easily soluble in spirit of wine, particularly in boiling spirit. Even in these solutions, basic salts are easily formed. The addition of water to these solutions produces a precipitate. (Thudichum.)

Leucate of Magnesium.—Sparingly soluble in water, deposited in crusts on evaporation. (Thudichum.)

Leucates of Mercury.—Mercuric Leucate may be prepared:—*a.* Directly, by dissolving freshly-precipitated moist mercuric oxide in aqueous leucic acid. A flaky precipitate gradually ensues, which on heating becomes red and granular, and adheres to the sides of the glass. On cooling, a new precipitate, consisting of whitish globules, is deposited.—*b.* By adding mercuric nitrate to an aqueous solution of leucic acid, a whitish-red precipitate is formed, which dissolves on boiling, and on cooling is again deposited in reddish granules.—*c.* By adding the mercurial solution to the leucate of an alkali-metal.

Mercurous Leucate.—When a solution of mercurous nitrate is added to a solution of leucic acid a slight turbidity ensues. The addition of carbonate of sodium produces a copious reddish-white precipitate, which, on boiling, becomes red, then dull grey, and deposits metallic mercury. (Thudichum.)

The leucates of mercury have a great tendency to become reduced. The mercuric salt easily passes into the mercurous salt. The mercuric salt, moreover, has a great tendency to become basic and insoluble. (Thudichum.)

Leucate of Potassium is produced by the action of aqueous potash on leucic ether, and separates as a semi-solid soap on the surface of the potash-solution, if the latter is concentrated. (Frankland.)

Leucates of Silver.—a. The *neutral-salt*, $C^6H^{11}AgO^3$, is obtained by adding nitrate of silver to the solution of the acid neutralised with ammonia, or by boiling the acid with oxide of silver, and may be rendered quite colourless by recrystallisation from boiling water, in which it is moderately soluble. It is anhydrous (Waage). Nitrate of silver added to a warm solution of leucate of ammonium, potassium, or sodium, forms a copious white crystalline precipitate, which increases as the liquid cools, and blackens if left in the mother-liquor (Thudichum). It contains 45·2 per cent. silver (Waage); 44·14 (Thudichum); calc. 45·19 per cent.

Acid salt, $C^6H^{11}AgO^3.C^6H^{12}O^3$.—A hot dilute solution of leucic acid decomposes recently

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precipitated carbonate of silver, with effervescence. The excess of the carbonat and the undissolved portion of the leucate become blackish-grey, but the a entirely neutralised. The hot filtrate forms no deposit on cooling. The evaporate it over the water-bath produces a black precipitate of reduced must, therefore, be evaporated in vacuo over oil of vitriol. After prolonged a few crystals, of a glassy lustre and appearing under the microscope as rhombic plates, are deposited at the margin of the dish. The liquid the covered with a pellicle, and evaporation is impeded. At a later stage conglo needles are deposited, which, when carefully dried over sulphuric acid appear a little blackened, like most silver-salts, but are not decomposed. analysis 26·97 per cent.; the formula requires 29·1 per cent. (Thudichum

Leucate of Sodium.—The aqueous acid neutralised with carbonate of so evaporated, leaves a syrupy residue covered with a crystalline crust. When is left over oil of vitriol, crystals form in it, which under the microscope exhi racteristic tub-shape, with rhombic plates interspersed here and there. (Thu

Leucate of Zinc, $Zn''(C^6H^{11}O^3)^2$.—This salt is obtained by neutralising acid at the boiling heat with carbonate of zinc, and filtering at the same te The solution deposits a thin crust on cooling. Evaporated over the wat soon becomes covered with a crust, and on cooling deposits bulky masses o which must be separated by filtration, pressed between bibulous paper, and exposure to the air or over the water-bath. The best crystals are obtain solution containing excess of leucic acid (Thudichum). For Waage's mo paration, see page 575.

The salt is snow-white, with splendid silky lustre; exhibits under the m the appearance of masses of needles (Thudichum); extremely light dazzling whiteness and silky lustre (Waage). It is sparingly soluble even water, less in cold water (Thudichum); dissolves in 300 pts. water at 1 204 pts. boiling water; more soluble in alcohol (Waage). The air-dried sal $Zn''(C^6H^{11}O^3)^2.H^2O$, and gives off its water (5·1 per cent.) at 100° (Waa anhydrous salt gives by analysis, 43·87 per cent. carbon, 6·39 hydrogen, zinc, the formula requiring 44·01 carbon, 6·72 hydrogen, and 19·92 zinc (Thu Sulphydric acid precipitates the zinc completely (Waage); according to T on the contrary, the precipitation is only partial, even after the solution repeatedly saturated with the gas.

LEUCIC ETHER. *Leucate of Ethyl*, $C^8H^6O^3 = C^6H^{11}(C^2H^5)O^3$.—The and preparation of this compound by the action of zinc-ethyl on oxalic e already been described (p. 575). It is a colourless, transparent, somewhat o possessing a peculiar penetrating ethereal odour, and a sharp taste. It is in water, but dissolves readily in alcohol and ether. Specific gravity 0·9613 Boiling point, 175°. Vapour-density, obs. = 5·241; calc. 5·528. Tre hydrate of barium or potassium, it yields the corresponding salts of le (Frankland.)

LEUCINDIN-SULPHURIC ACID. See INDIN-SULPHURIC ACID (p.

LEUCINE. $C^6H^{13}NO^2$. Formerly called *Aposepedine* and *Caseous Oxide.* Ann. Ch. Phys. [2] x. 40; Braconnot, *ibid.* xiii. 119; Mulder, J. pr. C 290; Bopp, Ann. Ch. Pharm. lxix. 20; Laurent and Gerhardt, Ann. [3] xxiv. 321; Cahours, Compt. rend. xxvii. 265; Limpricht, Ann. Ch. Ph 243; Gössmann, *ibid.* xc. 184; xci. 129; Strecker, *ibid.* lxviii. 54; Gm —This substance was first observed by Proust, in 1818, as a product of the pu of cheese; and Braconnot in 1820 found it among the products of decomp animal substances by sulphuric acid; Mulder, in 1838, showed that the two thus obtained were identical.

It is homologous with glycocine ($C^2H^5NO^2$) and alanine ($C^3H^7NO^2$), an regarded as lactamic acid, $(C^6H^{10}O)''\begin{matrix}H^2\\H\end{matrix}\}\begin{matrix}N\\O\end{matrix}$, being related to leucic acid in manner as glycocine to glycollic acid, and alanine to lactic acid.

Occurrence.—In old cheese (Proust). In fresh calf's liver (Liebig, Che 3 Aufl. 453); also, together with tyrosine, in the human liver, in certain disease, but not in the healthy liver (Frerichs and Städeler, Jahresbe 675). According to later researches by these chemists (*ibid.* 1856, 702; 1858, cine and tyrosine are very widely diffused in the animal organism. Leucine a together with taurine, inosite, and uric acid, in the tissue of the lungs (A. Ann. Ch. Pharm. xcii. 289). According to Gorup-Besanez, Ann. Ch xcviii. 7), it occurs in many parts of the glandular system, viz., in the thy thyroïd glands, in the liver, and especially in the pancreas. It has been fou

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the brain of oxen (W. Müller, Ann. Ch. Pharm. ciii. 131); in the pancreas of oxen (Scherer, Jahresber. 1859, p. 610); in the stomach and intestines of the pupæ of butterflies (Schwarzenbach, *ibid.* 1857, p. 538), and in the fly-agaric, *Agaricus muscarius.* (Ludwig, *ibid.* 1862. p. 516.)

Formation.—1. In the decomposition of gelatin, muscular flesh, legumin or wool (or white of egg, according to Mulder), by sulphuric acid (Braconnot); together with a small quantity of glycocine (Mulder). Gorup-Besanez also (Ann. Ch. Pharm. cxviii. 230), by treating wool with sulphuric acid, obtained, together with volatile acids and a large quantity of ammonia, about 3 per cent. of tyrosine, and a rather large quantity of leucine containing sulphur. The leucine was obtained free from sulphur by dissolving it in rather dilute potash-ley, boiling it with a solution of lead-oxide in potash, filtering from sulphide of lead, neutralising the filtrate with sulphuric acid, evaporating to dryness, boiling the pulverised residue with alcohol, and leaving the solution to crystallise.

2. By heating horn with dilute sulphuric acid (Hinterberger), also together with tyrosine, by heating elastic tissue, especially the cervical ligament (Zollikofer), or feathers, hedge-hogs' spines, human hair, the wing-cases of cockchafers, or globulin and hæmatin from ox-blood (Leyer and Köller, Ann. Ch. Pharm. lxxxiii. 332), or silk (Hinterberger, Wien. Akad. Ber. xi. 450) or conchiolin (Schlossberger, Zeitschr. Ch. Pharm. 1860, p. 424), with dilute sulphuric acid. Erlenmeyer and Schöffer (Zeitschr. Ch. Pharm. 1859, p. 315), by boiling 1 pt. of various albuminous and gelatinous substances with 5 pts. of a mixture of 1 pt. sulphuric acid (H^2SO^4) and 1½ pts. water, obtained the following quantities of leucine and tyrosine: Cervical ligament yielded ¼ per cent. tyrosine and 38 to 45 per cent. leucine; blood-fibrin, 2 per cent. tyrosine (on evaporating the neutral liquid to about 1·08 to 1·10 specific gravity), then 14 per cent. leucine; flesh-fibrin, not quite 1 per cent. tyrosine, and about 18 per cent. leucine; white of hen's egg, 1 per cent. tyrosine and about 10 per cent. leucine; horn (treated with 10 pts. of the above acid mixture), 3·6 per cent. tyrosine, and about 10 per cent. leucine. The several substances were decomposed by three hours' boiling with the acid as completely as when the boiling was continued for 36 or 40 hours.

3. By the action of dilute acids upon indican. (Schunck, p. 247.)

4. By boiling white of egg, gelatin, or flesh, with potash-ley, glycocine being formed at the same time (Mulder). Hence also, when the juice of mangold-wurzel is boiled with lime. (Hochstetter, J. pr. Chem. xxix. 36.)

5. By melting albumin, fibrin, casein (Bopp), or horn (Hinterberger) with hydrate of potassium.

6. In the putrefaction of casein or gluten under water (Proust, Mulder); sometimes abundantly, sometimes only in traces (Cahours). Also, together with tyrosine, ammonia, butyric acid, and lactic acid, by the putrefaction of yeast (A. Müller, J. pr. Chem. lvii. 162, 447). But according to Hesse (J. pr. Chem. lxx. 34), the substance regarded by Müller as leucine contains 3 or 4 per cent. sulphur, and is more soluble in alcohol than leucine (see PSEUDOLEUCINE, p. 582).

7. By the action of hydrocyanic acid and dilute hydrochloric acid, with the aid of heat, on valeral-ammonia (Parkinson, Ann. Ch. Pharm. xc. 144; Limpricht, *ibid.* xciv. 243):

$$NH^3.C^5H^{10}O + CNH + HCl + H^2O = C^6H^{13}NO^2 + NH^4Cl.$$

It was stated by Gössmann, that thialdine is converted into leucine by the action of moist silver-oxide, according to the equation:

$$C^6H^{13}NS' + 2Ag^2O = C^6H^{13}NO^2 + 2Ag^2S;$$

but according to Hofmann (Chem. Soc. J. x. 193), thialdine thus treated gives off the whole of its nitrogen in the form of ammonia.

Preparation.—1. Finely-chopped beef, washed with water and then strongly pressed, is mixed with an equal weight of oil of vitriol, and gently heated till it is completely dissolved; the fat is skimmed off after cooling; the mixture diluted with water amounting to 3½ times the weight of the meat; the liquid boiled for 9 hours, with frequent renewal of the water; the sulphuric acid removed by chalk; the filtrate evaporated to an extract; this extract repeatedly boiled with alcohol of 34° Bm.; the resulting alcoholic tincture evaporated; the dry residue exhausted with cold alcohol; the residual mixture of leucine and a small quantity of matter precipitable by tannin dissolved in water; a solution of tannin carefully added to it by drops as long as any precipitate ensues; and the liquid filtered after a few seconds, then evaporated (Braconnot). The leucine prepared by Braconnot appears still to have contained glycocine. (Mulder.)

2. 1 pt. of dry albumin, fibrin, or casein, free from fat, is boiled with 4 pts. of oil of vitriol and 12 pts. of water, in an open vessel, the ebullition being continued for a day

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and the water continually renewed. Or, better: 1 pt. of the substance is dis
4 pts. of strong hydrochloric acid; the liquid mixed with 3 or 4 pts. of oil of vi
evaporated over the water-bath till the greater part of the hydrochloric acid is
and the remaining black-brown pitchy or syrupy mass, in which minute cryst
is dissolved in hot water. Either of these acid liquids is boiled with excess o
lime to expel ammonia, then strained through a linen bag; the clear filtrate trea
sulphuric acid to precipitate the lime which is held in a solution by a produ
composition; the excess of acid precipitated by acetate of lead, and the exces
by sulphydric acid; and the filtrate evaporated to a syrup, from which in a
leucine and tyrosine crystallise. The crystals are freed from the syrupy moth
by digestion in 86 per cent. alcohol, and the leucine separated from the tyro
brown matter by treatment with water, hydrated oxide of lead, and animal
as in the fifth mode of preparation.

3. 1 pt. of cow-horn shavings is boiled with 4 pts. of oil of vitriol and 12 pts.
for 36 hours, the water being renewed from time to time, the liquid then supers
with milk of lime; the whole boiled for 24 hours in an iron pot, then strained
a conical bag and squeezed, and the liquid mixed with a very slight excess of s
acid, filtered, and evaporated; it then yields at first spherical crystalline m
tyrosine, and afterwards laminated masses of leucine. The latter are pressed
paper, freed from brown matter by washing with absolute alcohol, and crystalli
solution in a small quantity of hot water, tyrosine then separating first, and the
liquor afterwards yielding leucine, tolerably pure but not quite white. It must
be dissolved in hot water; digested with a small quantity of hydrated oxide of l
liquid filtered; the filtrate freed from lead by sulphydric acid, and the crystallise
further treated with animal charcoal (Hinterberger, Ann. Ch. Pharm. l
H. Schwanert (*ibid.* cii. 221) boils 2 lbs. of horn-shavings with 5 lbs. sulph
and 13 lbs. water for 24 hours, renewing the water as it evaporates, then supers
with lime, and, after filtering off the gypsum, evaporates the filtrate to 12 lbs. ar
it with a quantity of oxalic acid sufficient to produce a slight acid reaction. Th
filtered from calcic oxalate, and evaporated till a crystalline film forms upon its
deposits groups of yellowish laminæ of leucine mixed with tyrosine, more of which
may be obtained by evaporating the mother-liquor. The crystalline mass is t
solved in such a quantity of hot water that the solution on cooling yields cr
tyrosine only; the leucine solution is then decolorised with animal charcoal, eva
and the leucine which separates is purified by pressure and recrystallisation f
alcohol. Waage (Ann. Ch. Pharm. cxviii. 295) proceeds in the same way as Sch
excepting that, after precipitating the last portions of lime with oxalic acid, he m
filtrate with sulphate of copper, precipitates the copper with sulphydric acid; ev
the filtered liquid which is then nearly colourless, to the crystallising point; re
lises the separated leucine from water and dilute alcohol; and finally decoloris
boiling with a small quantity of hydrate of lead, and removing the lead by
dric acid. The leucine thus prepared still retains 2 per cent. ash and a trace of

4. White of egg, gelatin, or flesh, is boiled with potash-ley till it is comple
composed; the liquid neutralised with sulphuric acid, and evaporated; and the
extracted with alcohol. (Mulder.)

5. 1 pt. of the powder of dry albumin, fibrin, or casein free from fat, is added
of hydrate of potassium, heated to fusion in an iron crucible of 25 times the c
and water carefully added after half an hour, when the violent frothing arisi
the escape of water and ammonia has subsided, and the brown colour which t
ture at first exhibits, is changed to yellow; if the liquid be then saturated wit
acid, filtered hot, and gradually cooled, it yields tufts of needles consisting of t
These crystals completely fill the filtrate, when the process is well conducted;
other hand, they are less abundant the longer the fusion has been continue
liquid decanted from the crystals of tyrosine is evaporated till a crystalline film
on the surface; then set aside for 24 hours and exhausted with strong alcoho
leaves crystals of leucine and the still remaining tyrosine; the liquid is mix
alcoholic sulphuric acid, and decanted from the crystallised sulphate of potassi
alcohol separated from it by evaporation, the sulphuric acid by lead, and then
by sulphydric acid; and the solution finally evaporated, whereupon it yields cr
leucine and a greasy syrup, the quantity of which is less in proportion as th
has been longer continued. To purify the leucine from tyrosine and a small
of brown colouring matter, it is dissolved in such a quantity of hot water tha
small quantity of leucine may separate on cooling, together with the tyrosi
mother-liquor is digested with hydrated oxide of lead, which removes the c
matter together with a small quantity of leucine; the filtrate is treated with su
acid; and the filtrate thus obtained, which has merely a yellowish colour, is eva
in a flask till a crystalline film forms on its surface. It then, on cooling, yields

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f leucine, which must be washed with cold water and alcohol, and decolorised by reatment with animal charcoal and recrystallisation.—If the object be merely to obtain eucine, and not tyrosine, it is sufficient to heat the potash-mixture till the strongest ntumescence is over. At that stage of the process, the same quantity of leucine is ormed, but no tyrosine. (Bopp.)

6. One pt. of cheese, muscular flesh, or white of egg, is left to putrefy with 50 pts. f water for six weeks at a temperature somewhat above 20°; the resulting turbid olution boiled with a small quantity of milk of lime; the lime precipitated by a very light excess of sulphuric acid; the filtrate boiled down and precipitated by neutral cetate of lead; the decanted liquid treated with sulphydric acid; the filtrate evaporated o a syrup; and the leucine which crystallises therefrom, is freed from the remaining yrup by means of alcohol, and purified by solution in water, treatment with hydrated xide of lead and sulphydric acid, crystallisation, and washing with cold water and lcohol. When the above-mentioned alcoholic solution of the syrup is evaporated to omplete dryness, and the residue dissolved in absolute alcohol, the solution still leposits a small quantity of leucine. (Bopp.)

7. The cervical ligament of the ox, after being freed from the surrounding fibrous issue by boiling with water containing acetic acid, and subsequent scraping with a nife, and (if necessary) from fat by digestion in ether, is boiled for 48 or 50 hours with dilute sulphuric acid (8 pts. oil of vitriol to 12 pts. water), the water being replaced as it evaporates. The resulting solution is mixed with a slight excess of thin milk of lime, and boiled for some hours; the filtrate exactly neutralised with sulphuric acid and evaporated; and the liquid, after filtration from the separated sulphate of calcium, is again evaporated: it then yields, especially on cooling, impure leucine, which may be purified by recrystallisation from hot alcohol. This process is peculiarly advantageous, as the acid mother-liquors crystallise to the last drop, yielding nothing but leucine. (Zollikofer, Ann. Ch. Pharm. lxxxii. 162; compare Gössmann, *ibid.* xci. 130.)

8. Valeral-ammonia is boiled in a retort with hydrocyanic and hydrochloric acids till the oily layer consisting of the fused ammonia-compound has completely disappeared; the solution is then left to itself till the greater part of the resulting chloride of ammonium has crystallised out; the hydrochloric acid removed by means of hydrated oxide of lead, and the lead by sulphydric acid; the filtrate is evaporated over the water-bath, and the residue dissolved in hot dilute alcohol: the solution thus obtained yields crystals of pure leucine. (Limpricht.)

Properties.—Leucine crystallises from alcohol in soft nacreous scales, lighter than water and resembling cholesterin. It sublimes completely at 170°, in cotton-like flocks without fusion or decomposition (Mulder); according to Schwanert, on the contrary, it melts at 170°. It is sparingly soluble in cold, but dissolves easily in hot *water*; sparingly in alcohol of ordinary strength (in 658 pts. of cold alcohol of specific gravity 0·828 according to Mulder), very sparingly in absolute alcohol. According to Zollikofer, it dissolves in about 27 pts. of cold water, in 1040 pts. of cold alcohol of 96 per cent., and in 800 pts. hot alcohol of 98 per cent. It is insoluble in ether. Its solubility in water and alcohol is increased by the presence of acetic acid, or an alkaline acetate.

Decompositions.—1. Leucine heated to 180°, yields a yellow distillate having an ammoniacal odour, and solidifying in the cold, while a brown resinous mass remains in the retort. The alcoholic solution of the distillate has an alkaline reaction, and when treated with hydrochloric acid, gives off carbonic anhydride, and yields a solution containing hydrochlorate of amylamine, together with sal-ammoniac. The resolution of the leucine into carbonic anhydride and amylamine, which is the principal reaction, is similar to that of phenyl-carbamic acid into carbonic anhydride and phenylamine, and shows that leucine may be regarded as amyl-carbamic acid:

$$\underset{\text{Leucine.}}{C^6H^{13}NO^2} = CO^2 + \underset{\text{Amylamine.}}{C^5H^{13}N}. \quad \text{(Schwanert.)}$$

—2. Leucine heated in contact with the air burns readily, and with a white flame. —3. An alkaline solution of leucine exposed to the action of *ozone*, yields carbonic acid, butyric acid, and other volatile fatty acids, ammonia, and probably also, in the earlier stage of the decomposition, cyanic acid and valeraldehyde (Gorup-Besanez, Ann. Ch. Pharm. cxxv. 210).—4. Leucine is decomposed by *chlorine*, forming a hard brown body, similar to that obtained with glycocine (ii. 903), and a red volatile liquid (Mulder). When chlorine is passed into water in which leucine is suspended, carbonic anhydride is evolved, and a turbid solution is formed, from which an oily liquid separates, consisting of a mixture of valeronitrile and chloro-valeronitrile (C^5H^8ClN): the solution contains hydrochlorate of leucine (Schwanert). —5. *Sulphuric anhydride* is rapidly absorbed by leucine, forming a brown viscid liquid, which at 100° gives off

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carbonic and sulphurous anhydrides, and if then distilled with water, y grant liquid boiling at 97°, and forming crystalline compounds with the a of the alkali-metals; probably, therefore, valeraldehyde (Schwanert).- heated for some time with a sufficient quantity of *nitric acid*, is comple into gases, but so long as the decomposition is incomplete, the still remai exhibits the characters of nitrate of leucine (Mulder).—7. When nit passed into a solution of leucine in nitric acid, nitrogen is evolved, and le $C^6H^{12}O^3$, is formed (Strecker, p. 575). The same acid is formed whe passed, not in excess, into a dilute solution of leucine in caustic soda (G —8. Chlorine gas passed to saturation into a solution of leucine in carbon sium, forms chloride of cyanogen, valerianic acid, and valeronitrile (G —9. Leucine distilled with *peroxide of manganese* and dilute *sulphuric* valeronitrile and carbonic anhydride:

$$C^6NH^{13}O^2 + O^2 = C^5H^9N + CO^2 + 2H^2O.$$

When stronger sulphuric acid is used, valerianic acid passes over, and the tains ammonia. When leucine is distilled with *peroxide of lead* and v trace of valeronitrile passes over, but a large quantity of butyral and th which crystallise together in the form of butyral-ammonia.—10. By *perm* it is resolved into ammonia, oxalic acid, and valerianic acid (Neubau Pharm. cvi. 59).—11. Leucine fused with *hydrate of potassium*, gives off a hydrogen and forms valerate of potassium (Liebig, Ann. Ch. Pharm 12. An aqueous solution of leucine emits a very offensive odour, and form acid, perhaps leucic acid (Cahours).—In a vacuum, the aqueous solutio appears to remain undecomposed (Gössmann).—13. When a solution leucine in water is set aside for some weeks in contact with a quantity of which in the dry state would weigh ½ pt., putrefaction takes place, part of the leucine is decomposed, and ammonia is produced, together v quantity of valerianic acid as cannot be wholly produced from the fibrin.

Combinations.—1. With acids. Leucine dissolves easily in acids, formin able salts. The *hydrochlorate*, $C^6H^{13}NO^2.HCl$, forms crystals very soluble in *nitrate*, $C^6H^{13}NO^2.HNO^3$, called also *nitroleucic acid*, forms colourless needl *of leucine and barium* contains 41·01 per cent. baryta (Mulder). *Nitra and calcium* forms mammellated groups containing water of crystallisation. *leucine and magnesium* forms small granular crystals. Leucine also forms salt with *nitrate of silver*. These salts have probably the formula $C^6H^{12}N$

2. With bases. Leucine dissolves readily in caustic *alkalis*, but without them. The aqueous solution of leucine does not precipitate the solution of salt excepting basic acetate of lead.

Cupric salts.—Recently precipitated cupric oxide dissolves readily in aqu forming a bluish liquid, which, on cooling, deposits crystalline grains having the colour of ammoniacal sulphate of copper, and containing CuO

or $C^{12}H^{24}C''uN^2O^4.H^2O$. (Gössmann.)

Lead-salts.—On cautiously adding ammonia to a boiling aqueous solutio and neutral acetate of lead, nacreous scales are deposited containing PbO.2 $C^{12}H^{24}Pb''N^2O^4.H^2O$ (Strecker, Ann. Ch. Pharm. lxxii. 89). Gössmann salt of the same composition; but in one experiment, perhaps in conse peculiar degree of concentration, he obtained laminated groups of crystals lepidolite, and containing $9PbO.2C^6H^{13}NO^2$.

Mercuric salt.—Recently precipitated mercuric oxide dissolves very rea considerable quantity in aqueous leucine; and the solution, when evaporat first crystalline granules and afterwards laminæ containing 47·3 per ce oxide: therefore $HgO.2C^6NH^{13}O^2$ or $C^{12}H^{24}Hg''N^2O^4.H^2O$. (Gössmann Aqueous leucine is not precipitated by mercuric nitrate or chloride; but of potash or ammonia, a white bulky precipitate is formed, which dissolv of potash: the precipitate gradually becomes gelatinous and decomposes du (Gössmann). According to R. Hoffmann, on the contrary (Ann. Ch. Ph 123), pure leucine is precipitated by mercuric nitrate in white flakes, colouring of the supernatant liquid, the production of such a colour in presence of tyrosine.

Aqueous leucine added to a solution of *mercurous nitrate* throws dow dance of white flocks, the supernatant liquid acquiring a red colour. (Br

Pseudoleucine. This name is applied by Hesse (J. pr. Chem. lx sulphuretted compound nearly related to leucine, found by A. Müller products of the decomposition of yeast (p. 579). It contains 3 or 4 per c and is perhaps $C^{36}H^{78}N^6O^{12}S$. It is more soluble in alcohol than leucin

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purified as completely as possible, forms a white spongy mass composed of shining laminæ. When cautiously heated, it sublimes almost without decomposition. It melts at 210°, and when distilled in an atmosphere of carbonic anhydride, yields, together with more volatile compounds containing nitrogen and sulphur, a woolly mass of acicular crystals resembling phlorizin, having the composition $C^6H^{11}NO$, and dissolving in dilute soda-ley with evolution of ammonia; this substance is designated by Hesse, **leuconitrile**. The other products of the dry distillation of pseudoleucine are sulphydric acid, hydrocyanic acid, a brownish, tarry, fetid substance, and several volatile bases, including ammonia, methylamine, dimethylamine, tritylamine, and a considerable quantity of amylamine.

LEUCITE. A silicate of aluminium and potassium, $(K\overline{\overline{Al}})Si^2O^6$, occurring in monometric crystals, the usual form being the ikosi-tetrahedron or trapezohedron, hence called leucitohedron (*fig.* 180, ii. 125). Cleavage cubic, very imperfect; surface of crystals even, but seldom shining. The mineral often occurs disseminated in grains, rarely in granular masses. Hardness = 5·5 to 6. Specific gravity = 2·483 to 2·49. Lustre vitreous. Colour ash-grey or smoke-grey, white. Streak uncoloured. Translucent to opaque. Fracture conchoïdal. Brittle. Infusible before the blowpipe, except with borax or carbonate of calcium, with which it melts with difficulty to a clear globule. Gives a fine blue with cobalt-solution.

Analyses.—*a.* From Albano near Rome (Klaproth, *Beitr.* ii. 39).—*b.* From Pompeii (Klaproth, *ibid.*).—*c.* From Somma (Awdejew, Pogg. Ann. lv. 107).—*d.* From Vesuvius, eruption of 1811 (Rammelsberg, *ibid.* xcviii. 143).—*e.* From Vesuvius, eruption of 1845 (Rammelsberg, *ibid.*).—*f.* From Rieden on Lake Laach (Bischof, *Chem. Geologie*, ii. 2288):

	a.	*b.*	*c.*	*d.*	*e.*	*f.*
Silica . .	54	54·5	56·05	56·25	57·84	56·22
Alumina . .	23	23·5	23·03	23·26	22·85	23·07
Potash . .	22	19·5	20·40	20·04	12·45	13·26
Soda . .	. .	. .	1·02	0·43	6·04	6·40
Lime . .	. .	. .	. .	0·32	0·20	0·23
Ferric oxide .	. .	. .	. .	. .	0·14	0·48
Loss by ignition	. .	. .	. .	. .	0·59	
	99	97·5	100·50	100·30	100·11	99·66

The formula $(K\overline{\overline{Al}})Si^2O^6$ or $K^2O.Al^2O^3.4SiO^2$ requires 55·58 silica, 23·16 alumina, and 21·26 potash. The potash is sometimes replaced to a considerable extent by soda, as in *e.* and *f.* Abich found in a specimen from Vesuvius a still greater amount of soda.

Leucite occurs in volcanic formations, both ancient and modern; it is abundant in trachyte between Lake Laach and Andernach on the Rhine; the finest and largest crystals are, however, obtained from Vesuvius. Near Rome, at Borghetta on the north, and Albano and Frascate to the south, some of the older lavas appear to be almost entirely composed of it. This leucitic lava is used to form millstones, and millstones made of it have been discovered in the excavations at Pompeii.

Leucite occurs altered to felspar, nephelin, and kaolin. Leucite altered to glassy felspar has been observed on Somma by Scacchi. (Dana, ii. 231; Rammelsberg, *Mineralchemie*, p. 645.)

LEUCOCYCLITE. Syn. with APOPHYLLITE.

LEUCOHARMINE. Syn. with HARMINE.

LEUCOLINE. An organic base obtained from coal-tar, isomeric with chinoline, C^9H^7N. The two bases having this composition, the one obtained by the dry distillation of quinine and cinchonine, the other among those of the distillation of coal, were formerly thought to be identical, and the name chinoline was applied to both. Subsequent researches, however, having pointed out important differences between the two, especially in their behaviour with iodide of amyl, the base obtained from cinchonine is now distinguished as chinoline, and the coal-tar base (originally called *leucol* by Runge, who discovered it) as leucoline (see i. 869).

Each of these bases has a series of homologues corresponding with it, and differing in a similar manner from their isomers in the other series. The following names have been proposed by Greville Williams (Chem. Soc. J. xvi. 377) to distinguish the isomeric bases of the two series:

Coal series.		*Cinchonine series.*
Leucoline . .	C^9H^7N . .	Chinoline
Iridoline . . .	$C^{10}H^9N$ . .	Lepidine
Cryptidine . .	$C^{11}H^{11}N$ . .	Dispoline

The higher homologues of chinoline, as far as $C^{16}H^{21}N$, have also been obtained; the corresponding bases in the leucoline series are at present unknown. (Proc. Roy. Soc. xiii. 312.)

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LEUCOLITE. Syn. with PYCNITE.

LEUCONE. $Si^4H^6O^5$.—A white substance obtained by the deco silicone, $Si^4H^4O^3$, under the influence of light and water (Wöhler, Ann. cxxvii. 268). See SILICIUM.

LEUCONIC ACID. *Oxycroconic acid*, $C^5H^6O^6$. (Will, Ann. Ch. P 117; Lerch, *ibid.* cxxiv. 20.)—An acid produced from croconic acid oxidation and assumption of water:

$$C^5H^2O^5 + O + 3H^2O = C^5H^8O^9.$$

When a solution of croconate of potassium is treated with chlorine or nit decolorised and converted into leuconate of potassium, in the latter cas tion of nitric oxide.

The acid [? prepared by decomposing the barium-salt with sulphuric a colourless syrup, which when heated above 100° turns yellow, and is co croconic acid. It is tribasic, and forms white or pale yellow salts, which being easily converted into croconates, especially in presence of alkalis.

The *barium-salt*, $C^{10}H^{10}Ba^3O^{18}$, is obtained as a flocculent, yellowish-wh tate by adding baryta-water to the solution of the potassium-salt, prepar till it becomes alkaline. (Will.)

The *lead-salt*, $C^{10}H^{10}Pb^3O^{18}$, and the *silver-salt*, $C^5H^2Ag^3O^9$, are light-yel tates.

Potassium-salt. When a solution of croconate of potassium decoloris with chlorine or nitric acid, is neutralised with caustic potash or carbonate o the liquid, just at the point of saturation, exhibits a transient play of c colourless to purple-red, bluish-red and yellowish; and if the solution is c an abundant yellowish-white precipitate is formed at the same time, whic in a large quantity of water. This precipitate was found by analysis to h position $C^5H^7KO^9$, but the lead-salt obtained from it by precipitation wit lead exhibited the normal composition $C^{10}H^{10}Pb^3O^{18}$, whence it is probal sparingly soluble potassium-salt with 1 at. metal really consisted of the tri mixed with free leuconic acid (Will). According to Lerch, the solution o potassium-salt is decomposed by neutralisation with potash, yielding a sm of a black salt, probably dihydrocarboxylate of potassium (p. 190), to oxalate and a colourless crystallised potassium-salt.

LEUCONITRILE. A product of the decomposition of pseudoleucin

LEUCOPHANE. A silicate of glucinum and calcium, occurring together with albite, elæolite and yttrotantalite, on a small rocky islet nea of the Langesundfiord in Norway, where it was found by Esmark. It is tr imperfect cleavage in three directions inclined to one another at angles of 53 but usually occurs massive and columnar. Hardness = 3·5 to 4. Specif 2·974. It is more or less translucent, with pale dirty green or light wine-y and yields a white powder, strongly phosphorescent when heated or stru wise becomes electric when heated. It is optically biaxial. Before the melts to a clear bead with a tinge of violet, becoming turbid by flaming easily in borax to an amethyst-coloured glass; in phosphorus-salt it leaves silica; and with a small quantity of carbonate of sodium, it melts to a which, with a larger quantity of carbonate of sodium, sinks into the cha fused phosphorus-salt in an open tube, it gives the reaction of fluorine. an analysis by Rammelsberg (*Mineralchemie*, p. 764), it contains:

SiO^2	F	GO	Al^2O^3	CaO	MgO	Na^2O	K^2O
47·03	6·57	10·70	1·03	23·37	0·17	11·26	0·30

with traces of ferric and manganous oxides, a composition which may be by the formula, $4NaF.3(2CaO.2GO.3SiO^2)$.

Melinophane, from the zircon-syenite of Norway, is nearly related in co leucophane.

LEUCOPHYLL. A colourless substance isomeric with chlorophyll, Sacc (Jahresber. 1859, p. 561) to be contained in those parts of plant capable of turning green, and to undergo this change under the influenc rendered active by the agency of light. The existence of such a substance probable, according to Sacc, by the fact that the plasma of those vegetable quickly turn green on exposure to light, contains a substance which instan a bright verdigris-green colour when brought in contact with strong su and that the same reaction is exhibited by the ready-formed light green chlorophyll itself, whereas the plasma of cells which do not turn green i not exhibit it.

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i-arsenide of iron, $FeAs^2$, also called *arsenosiderite*

iacal solution of orceïn slightly acidulated with hy-
lorised by immersing a piece of zinc in it. If am-
precipitate called leucorceïn is formed, which on
t, and finally purple. (See ORCEIN.)

urent's *Oximide*. (Schlieper, Ann. Ch. Pharm.
solution of alloxanic acid (i. 138) is rapidly boiled
added, which leaves the leucoturic acid undissolved.
soluble in cold water, slowly but rather abundantly
crystallises on cooling. It is readily soluble in
pitated by mineral acids, and by the aid of heat de-
e potash-solution is decomposed by keeping or by
ed, and oxalic acid formed abundantly. The am-
ion crystals of the ammonium-salt, whose solution
eucoturic acid is not decomposed by boiling with
be monobasic. Schlieper found it to contain 31·15
and 24·51 nitrogen, whence he deduced the for-
carbon, 2·61 hydrogen, 24·35 nitrogen, and 41·74
e improbability of this formula, as it contains an
ogen and nitrogen. Baeyer suggests the formula
er cent. carbon, 1·89 hydrogen, 26·41 nitrogen, and

F. T. C.

OSAN. A product of the decomposition of cane-
ory power of 15° for the transition-tint (ii. 864).

nical process of grinding the parts of bodies to a
en the flat face of a stone called the muller, and a
ome liquid is always added in this process. The
one and muller over that of triturating in a mortar
sily be scraped together and subjected to the action
se to that of the pestle; and, from the flatness of the
e pressure. U.

nill for levigating litharge are given under LEAD

e of calcium and aluminium, occurring in rhombo-
sal face oR, which greatly predominates, and always
R. Angle R : R = 106° 4′; oR : R = 136° 1′; ratio
·8358 : 1. The crystals are often striated and often
Specific gravity = 2·09 to 2·16. Lustre vitreous.
vish. Transparent to translucent. Before the blow-
glass. When pulverised it dissolves in acids with-

Berzelius; *c.* from Skye, by Connel; *d.* from Ireland,
lchemie, p. 802):

	Na^2O	K^2O	Mg^2O	H^2O	
)	2·86	0·41	0·40	19·30 =	99·32
)	4·80	. .	. .	18·19 =	99·79
2	1·55	1·26	. .	19·51 =	100·81
1	1·38	1·61	. .	17·41 =	99·36

mula of chabasite. Damour's, which contains less
rmula:

$4H^2O$ or $(Ca''(Al^2)^{vi}H^4)Si^2O^{12}.2H^2O$,

ilicate.

t Glenarm; on Hatfield Moss, Renfrewshire; at Da-
Island, Greenland; and at Skagastrand in Iceland.

f augite from Lake Lherz in the Pyrenees, where it
ar, and of a deep-green or olive-green colour.

Procter, jun. (Am. J. Pharm. xxxi. 556), cumarin
the dried leaves of *Liatris odoratissima*, a plant
North America.

phosphate of copper, $4CuO.P^2O^5 + aq.$ or $Cu^3(PO^4)^2$.
ngary, and other localities. (See PHOSPHATES.)

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LICHENIC ACID. See FUMARIC ACID (ii. 741).

LICHENIN. $C^6H^{10}O^5$. (Gm. xv. 119.)—A substance isomeric with starc in several species of moss and lichen, especially in the so-called Iceland mo *islandica*), which is really a lichen. According to Maschke (J. pr. Chem formed from starch by the action of the free acid in the plant. It is ext Iceland moss by macerating the chopped lichen for twenty-four hours with a tity of cold water containing a small quantity of carbonate of sodium, and the treatment till the liquid no longer tastes bitter. It is then boiled with the boiling decoction is strained through a linen cloth. The liquid on coolin to a kind of jelly, which dries up to a hard brittle mass (Berzelius). Pay the bitter matter by washing the lichen successively with ether, alcohol gravity 0·83 and 0·90, cold water, very weak solution of carbonate of sodi hydrochloric acid of the strength of 1 per cent., and pure water. Dav N. Phil. J. xxviii. 260) macerates 112 lbs. of Iceland moss for a for potash-ley prepared from 4 lbs. of pearlash, or for six days with milk of li from 6 lbs. of lime, then washes with dilute hydrochloric acid, and water. Chloride of lime may also be used for the maceration. Knop and S mann (Ann. Ch. Pharm. lv. 164) treat Iceland moss with a large quantit chloric acid, and precipitate the solution, after dilution and straining, w The precipitated lichenin is then freed from water and rendered friable treatment with absolute alcohol, and freed from adhering hydrochloric mersion in running water.

Lichenin in the dry state forms a hard brittle mass, tasteless, but hav odour resembling that of lichens. In cold water it swells up without dissolves in boiling water, and is deposited in the form of a jelly; by prolon however, it loses the property of gelatinising, and is converted into a stance, probably dextrin. When the solution in boiling water is left to ev lichenin separates as a rough pellicle on the surface. Lichenin is insolubl and ether.

Dilute acids dissolve lichenin and convert it into glucose. *Nitric acid* it converts it into oxalic acid. Pure lichenin is merely coloured yellow by a green or blue colour is often produced, from admixture of starch.

LICHENS. The following enumeration of the proximate constituent is given by Rochleder in *Gmelin's Handbuch*, viii. 94:

Bæomyces roseus, Pers. See analysis by Brandes. (Berl. Jahrb. xxv.

Biatora lucida, Fr. Contains usnic acid. (Knop, Götting. gelehrte 1843, 2 u. 3 Stück, 16; and Ann. Ch. Pharm. xlix. 103.)

Cetraria aculeata, Fr. Contains no cetrarin, but moss-starch (lichenin) a (fumaric) acid. (Weppen, Pharm. Centr. 1838, No. 12.)

Cetraria islandica, Ach. Contains: fumaric acid (Schödler, Ann. xvii. 87) and cellular substance; starch not deposited in granules, but un tributed among the cells (lichenin); cetraric acid, lichenstearic acid, tall sugar, gum, yellow extractive matter, a brown substance formed from ce and a body not exactly determined (Knop and Schnedermann, lv. lichen always contains alumina (Knop, J. pr. Chem. xxxviii. 347). It cont quantity of a carbohydrate (lichenin) convertible into sugar. (C. Schmid Pharm. li. 29).

Cladonia digitata, Hoffm.
Cladonia macilenta, Hoffm. } contain starch. (Knop, *loc. cit.*)
Cladonia uncinata, Hoffm.

Cladonia pyxidata, Spr. Contains a large quantity of a carbohydrate into sugar. (C. Schmidt, *loc. cit.*)

Cladonia rangiferina, Hoffm. (*Lichen rangiferina*, L.) Contains (Rochleder and Heldt, Ann. Ch. Pharm. xlviii. 13), and a large quanti hydrate convertible into sugar. (C. Schmidt, *loc. cit.*)

Evernia furfuracea, Mann. (*Parmelia*, Ach.) Contains usnic acid (H and **Helot**, *loc. cit.*). See an analysis of this lichen grown on a pine-tre (Chem. Schr. vi. 41.)

Evernia ochroleuca, Fr. (*Parmelia sarmentosa*, Ach.) Contains usnic aci *loc. cit.*)

Evernia prunastri, Ach. Contains usnic and evernic acids (Stenhouse [3] xxxii. 300). Rochleder and Heldt found lecanoric, but not a tra acid.

Evernia vulpina. The experiments of Bebert (Ann. Ch. Pharm. ii. 3 so-called vulpulin, seem to show that this lichen contains chrysophanic aci lius, Jahresber. xii. 256.)

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Gyrophora pustulata, Ach. (*Umbelliaria*, Hoffm.) From Norway. Contains gyrophoric acid. (Stenhouse, Phil. Trans. 1849, p. 458.)

Isidium corallinum, Ach. Contains a large quantity of oxalate of calcium. (Braconnot, Ann. Ch. Phys. [2] xxviii. 319.)

Lecanora Parella, Ach. (*Parmelia*, Schaer.) Contains: three fats, tannin, parellic acid, lecanoric acid, chlorophyll, and gum, which gives a greenish-blue colour with iodine (Schunck, Ann. Ch. Pharm. liv. 257). The several species of *Lecanora* contain lecanoric acid. (Schunck, *ibid.* xli. 157.)

Lecidia candida, Ach. (*Psora*, Dec.) Contains a large quantity of oxalate of calcium. (Braconnot, *loc. cit.*)

Lecidia geographica, Schaer. From the Brocken. Contains usnic acid. (Knop, *loc. cit.*)

Parmelia ciliaris, Ach. (*Borrera ciliaris.*) See analysis by John. (Chem. Schr. vi. 39.)

Parmelia parietina, Ach. Contains chrysophanic acid, a yellow non-crystallisable colouring matter (Rochleder and Heldt, *loc. cit.*), and a carbohydrate convertible into sugar (C. Schmidt, *loc. cit.*) This lichen contains: a yellow and a red colouring matter, wax, crystalline stearin, chlorophyll, soft resin, gum, lichenin, vegetable mucilage, sugar, extractive matter, traces of volatile oil, and phosphate of calcium (Hesberger, Buchn. Repert. xlvii. 179); compare Sander (*Ueber die Wandflechte*, Sondershausen, 1815; and Kastn. Arch. viii. 431); Monnhardt (*Dissert. sist. Lobariæ parietinæ Analysin chem.* Kielonise, 1818); Schröder (Berl. Jahrb. 1819, p. 44); Markowitz (Scher. Ann. i. 438); Thomson (Ann. Ch. Pharm. liii. 252 and 260).

Parmelia physodes, Ach. Contains crystallised physodin. (Gerding, *Arch Pharm.* lxxxvii. 1.)

Parmelia saxatilis, Ach. Contains a small quantity of carbohydrate convertible into sugar. (C. Schmidt, *loc. cit.*)

Patellaria hæmatoma, Hoffm. (*Parmelia*, Ach.—*Patellaria rubra*, Hoffm.—*Parmelia*, Ach.—*Patellaria ventosa*, Dec.—*Parmelia*, Ach.) Contain large quantities of oxalate of calcium (Braconnot, *loc. cit.*). *P. hæmatoma* and *P. ventosa* contain usnic acid. (Knop, *loc. cit.*)

Patellaria tartarea, Dec. (*Parmelia*, Ach.) Contains large quantities of oxalate of calcium (Braconnot, *loc. cit.*) In a specimen from Norway, Stenhouse (*loc. cit.*) found gyrophoric acid. See analysis by N. v. Eserbeck (Ber. Arch. xvi. 135).

Peltigera canina, Hoffm. Contains a carbohydrate convertible into sugar. (C. Schmidt, *loc. cit.*)

Pertusaria communis, Dec. Contains a large quantity of oxalate of calcium.

Placodium ochroleucum, Dec. (*Parmelia saxicola*, Ach.) and *Placodium radiosum*, Dec. (*Parmelia radiosa*, Ach.) Contain very large quantities of oxalate of calcium. (Braconnot, *loc. cit.*)

Ramalina calicaris, Fr. var. *fastigiata*. Contains large quantities of starch, colouring matter and bitter substance, and a small quantity of saccharic acid (Berzelius, Scher. Ann. iii. 97). Contains usnic acid. (Rochleder and Heldt, *loc. cit.*)

Ramalina calicaris, Fr. var. *fraxinea*. The ash contains a large quantity of ferric oxide, but scarcely a trace of potash (John, Chem. Schr. vi. 37); soluble and coagulable albumin (Berzelius, Scher. Ann. iii. 208); lichenin, and usnic acid (Rochleder and Helot, *loc. cit.*)

Roccella Montagnei, Belen. Contains erythric acid. (Stenhouse, *loc. cit.*)

Roccella tinctoria, Ach. This lichen (var. *fuciformis*, from Angola and Madagascar) contains erythric acid (Heeren's erythrin, Kane's erythrilin, ii. 502), a fatty substance, roccellic acid, a brown substance extractable by potash, chlorophyll, and ash-constituents (Schunck, Phil. Mag. J. [3] xxix. 194). *Roccella tinctoria* from South America was found by Stenhouse (Phil. Mag. [3] xxxii. 300) to contain α-orsellic acid; the same lichen from the Cape of Good Hope contained β-orsellic acid and roccellinin. Stenhouse and Scouler are of opinion that the *Roccella tinctoria*, var. *fuciformis* analysed by Schunck, was really *R. Montagnei*.

Squamaria elegans, Fée. Contains chrysophanic acid. (Thomson, Ann. Ch. Pharm. liii. 266.)

Squamaria lentigera, Dec. (*Parmelia*, Ach.) Contains a very large quantity of oxalate of calcium. (Braconnot, *loc. cit.*)

Sticta pulmonacea, Ach. Contains lichenin and a bitter principle (Weppen, Pharm. Centr. 1838, No. 12) very near cetraric acid in composition, and named stictic acid by Knop and Schnedermann (J. pr. Chem. xxxix. 303); compare John (Chem. Schr. vi. 39).

Ulcolaria esculenta, Ach. Contains a large quantity (13 per cent.) of gum. (Kirchhoff, Scher. Ann. iii. 213.)

Ulcolaria scruposa contains a large quantity of oxalate of calcium (Braconnot, *loc. cit.*)

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Usnea barbata, Fr. Contains usnic acid (Rochleder and Heldt, lichenin. (Berzelius, Scher. Ann. iii. 205.)

Usnea barbata, Fr. var. *florida*. (*Usnea florida*, Hoffm.) Contai (Knop, *loc. cit.*), and a small quantity of carbohydrate convertibl (C. Schmidt, *loc. cit.*)

Usnea hirta, Hoffm. (*U. barbata* var. *plicata*, Fr.) Contains usnic *loc. cit.*), bitter principle, gum-sugar, lichenin and a soft skeleton (Berz Ann. iii. 203). Contains a large quantity of carbohydrate convertibl (C. Schmidt, *loc. cit.*)

Variolaria amara, Ach. Contains picrolichenin (Alms, Pharm. Zeit 17; Ann. Ch. Pharm. l. 61.) Contains chlorophyll, and a colourless, bitter substance, forming with ammonia a red non-bitter resin (Gregor Juin 1835, p. 314; Pharm. Centr. 1835, No. 39). Contains picrolicheni chlorophyll, gum-sugar, bitter extractive matter, oxalate of calcium, sili and cellulose (A. Müller, Pharm. Centr. 1844, No 47); compare Filh chardt. (J. de Méd. de Toulouse, vii. 201, and Pharm. Centr. 1844, N

Variolaria communis, Ach. (grown on a lime-tree). Contains waxy colouring matter, a bitter and acrid principle, uncrystallisable sugar, oxal (4·7 per cent.), a substance resembling animal gelatin, &c. (Brac Chim. Phys. [2] vi. 132.)

Variolaria dealbata, Dec. (*Lichen dealbatus*, Ach.) See analysis by Rol Ch. Phys. [2] lxii. 236), who found variolarin in this lichen, and prepared

On the colouring matters of lichens, see Archil, Erythric acid, E Gyrophoric acid, Lecanoric acid, Litmus, Orsellic acid, Orcin, Variolarin.

LICHENSTEARIC ACID. $C^{14}H^{24}O^{3}$. (Schnedermann, and Kn Pharm. lv. 149.)—An acid existing in Iceland moss (*Cetraria islandica*), also in the fly-agaric or toadstool (*Agaricus muscarius*) (Bolley, Ann. lxxxvi. 50). To prepare it, Iceland moss is boiled for a quarter of an h containing carbonate of potassium; the strained decoction is mixed with ex chloric acid; and the whole is diluted with 4 or 5 volumes of water. Th thereby formed is washed with water, and afterwards boiled three or fo alcohol of 42 to 45 per cent. On cooling the alcoholic solution, a mixt stearic and cetraric acids with a third substance, is separated, from whic stearic acid is taken up by boiling rock-oil, and again deposited on coo completely on partial distillation. Purification is effected by recryst alcohol, with the help of animal charcoal.

Properties.—The acid forms a loose, white mass, consisting of delica laminæ having a pearly lustre. From a solution in very dilute alcohol i in small rhombic tables; on concentrating the solution, partly in oily dro odorous, has a rancid, harsh, not bitter taste, melts at about 120° wi weight, and solidifies to a crystalline mass; is not volatile.

It is perfectly insoluble in *water*, but dissolves readily in *alcohol*, *ether*, fixed and volatile.

The *salts* of lichenstearic acid are permanent in the air, and are de acids, with separation of lichenstearic acid. Their solutions froth up on

Ammonium-salt.—The easily prepared solution of the acid in warm aq nia forms, on cooling, a white, elastic jelly, appearing under the microsco a quantity of long, extremely delicate crystals. The salt, when dry, is wh and only partially soluble in warm water, with loss of ammonia.

The *barium-salt*, $C^{28}H^{46}Ba''O^{6}$, is obtained, on precipitating the aqueous l of sodium with a soluble barium-salt, as a greyish white precipitate, wh gether in boiling water.

The *lead-salt*, $C^{28}H^{46}Pb''O^{6}$, is obtained, by precipitating the aqueous sod neutral acetate of lead, in white flakes, which, on boiling the liquid, melt semi-fluid mass. It is brittle, softens between the fingers, and becomes 100°, at which temperature also it appears to decompose.

Potassium-salt.—A solution of the acid in aqueous carbonate of potas down, when concentrated by evaporation, yellowish flakes, which are solu but insoluble in alkaline liquids. If the solution be evaporated to dry residue extracted with boiling absolute alcohol, a part of the salt is cooling, as an indistinctly crystalline powder; and the remainder, on conc solution, in the form of a syrup. It dissolves easily in water, forming liquid, which tastes like soap, and froths up on boiling.

The *silver-salt* is thrown down from a solution of the sodium-salt, by nitr as a greyish-white precipitate, turning violet on exposure to light, and cak in boiling water. It decomposes below 100°.

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the same manner as the potassium-salt. A concen-
wn white granules on standing.

e found in a red felspar porphyry on Mount Viesena,
ed in six-sided prisms, without distinct cleavage.
= 2·18. Colour greenish grey. Fracture splintery.
d intumesces, but does not fuse. Contains, according
7), 44·66 per cent. silica, 36·51 alumina, 1·94 ferric
, 0·92 soda, and 5·05 water (= 100·38). Marignac
ng to Blum, Breithaupt, and Haidinger, it is a pseu-
been regarded as an altered dichroïte. (Dana, ii.
hemie, p. 837.)

carbonate. See CARBONATES (i. 798).

aining 53·71 per cent. carbon, 8·95 hydrogen, 4·82
by Scherer (Jahresber. 1851, p. 597) in the fluid

e.—A silicate of iron and calcium, occurring in tri-
= 110° 12′; oP : P∞ = 146° 20′; ratio of principal
liagonal = 0·66 : 1 : 1·46. Observed combination,
P4 . ∞P∞ . ∞P∞ . P . 3P∞ . 2P∞ . ½P∞ . 2P2.
tudinally. Cleavage parallel to the longer diagonal,
mpact massive. Hardness = 5·5 to 6. Specific
etallic. Colour black, of various shades. Streak black,
e uneven. Brittle. Before the blowpipe it melts easily
and completely decomposed by hot hydrochloric acid.
nmelsberg's Mineralchemie, p. 740).- 2. Rammels-
(*ibid.*):

O	MnO	CaO	Al^2O^3	H^2O		
90	2·43	13·78	0·61	1·27	=	101·27
40	1·50	12·44	. .	1·60	=	100·32
60	0·94	15·49	. .	. .	=	100·27

osely with any simple formula, but they may be ap-
$2Fe^2O^3.6SiO^2$.
Elba, in large solitary crystals and aggregated crys-
is also found at Fossum and Skeen in Norway; in
Hartz; near Predazzo, in the Tyrol, in granite; at
Bytown, Canada.
granular mineral from Szurraskö in Hungary,
·12 alumina, 42·38 ferric oxide, 15·78 ferrous oxide,
and 1·00 water, is sometimes regarded as lievrite.
6 to 6·5), fuses with difficulty and only on the edges,
cids. (Dana, ii. 263.)

hich makes us acquainted with the existence of bodies
kewise one of the most important agents of chemical
ons, are absolutely dependent upon it for their exis-
r number of animals are incapable of living in health
influence; and a variety of chemical processes both
eat measure upon its agency.
een entertained respecting the nature of light may
tem of emission, and the system of undulations.
times by Empedocles and Democritus, afterwards
to the utmost degree of completeness of which it is
light to consist of minute particles emitted from
rough space with immense rapidity till they reach
germ of which may be found in the writings of
e rendered visible by vibrations excited by luminous
the ETHER, pervading all space, and filling up the
of ponderable bodies. Ideas similar to this were
nche, and Grimaldi; but it was in the hands of
umed a definite shape, and was rendered capable of
f known facts; and by the subsequent labours of
rs, it has been brought to such a state of perfection
most of the phenomena of light in their minutest
many important results, subsequently confirmed by
f emission, though it gave a satisfactory account of

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most of the phenomena known in Newton's time, is altogether unable to acc vast number of facts which have since been discovered. The wave-theory i now universally accepted as the true representative of the phenomena.

The existence of a fluid or medium, such as the theory supposes to ex celestial spaces, may be regarded almost as a matter of certainty: for the comets are found to be retarded in a manner which cannot be accounted other hypothesis. This phenomenon has been particularly studied in the case comet, which revolves about the sun in a period of three years. Now th found to be continually diminishing, showing that the comet is gradually a the sun, an effect which can only be accounted for by supposing its mo retarded by the action of a resisting medium. Moreover, as the light- transmitted freely, not only through the celestial spaces, but also through glass, and other transparent media, we must likewise suppose that the spac the molecules of these bodies are filled up by the ether. It will hereafte that the elasticity of the ether is different in different media.

In the present article, after speaking of the sources of light, we shall en show how the wave-theory is applied to explain the several phenomena of R Interference, Reflection, Refraction, Absorption, and Polari

The chemical action of light will be treated in a separate article.

Sources of Light.

The sun, the fixed stars, certain meteors, and terrestrial bodies in th incandescence and phosphorescence, shine by their own light; all other restrial or celestial, are visible only when the light of a self-luminous body them. Our knowledge of the peculiar conditions which render bodies se is not very exact; but assuming that vision is produced by undulations pervading elastic medium, we must suppose that these undulations are vibratory movements in the particles of luminous bodies. This suppositio over in accordance with the conclusions deduced from the phenomena of he The particles of all bodies are supposed to be in a state of constant mot depends upon the intensity and rapidity of this motion whether the effect p our senses by the undulations thereby excited in the surrounding ethereal that of heat alone, or of heat accompanied by light. We shall see he the non-luminous heat-waves are of less rapid vibration than those which li duce light. Accordingly when the temperature of a body is gradually rai gives out heat unaccompanied by light; but at a certain temperature, the become rapid enough to excite in the ethereal medium, waves which prod organs the sensation of red light, and at still higher temperatures vib produced of a rapidity corresponding to those which excite the sensation of of blue light, which, together with the red, produce the combined sensatio light. (See Radiation of Heat.)

A body may be raised to the temperature necessary to render it luminou chemical action (combustion) going on within its own mass (*e. g.* the burnin wood, hydrocarbons, &c.), or by heat imparted to it from without, as by the of a neighbouring body, by the electric current, by mechanical agen friction or percussion, or by the sun's rays concentrated upon it by a lens Matter in either of the three states of solid, liquid, and gas, may be brough candescent or self-luminous state; flame, indeed, is merely incandescent g explained in the article Combustion (i. 1094), solids become luminous at a temperature than gases, and give out much more light at any given te hence the brightest flames are those which contain suspended particles of s raised to a very high temperature by the heat of the combustion.

The light of the sun and of the fixed stars is in all probability due to inca indeed recent observations have shown that the luminous atmosphere contains many of the metals which exist in our own globe, and similar o have been made on several fixed stars.

Phosphorescence.—Many bodies, under peculiar circumstances, are t such a state of vibration that they emit light without perceptible evoluti Phosphorus, in the state of slow combustion which takes place on exposing at ordinary temperatures, gives off acid vapours, which shine in the dark w bluish light: hence the term *phosphorescent* has been extended to all bodie hibit a similar luminosity, from whatever cause it may arise. The phos of decayed bodies of plants and animals, as of dead wood and putrid familiar to every one. The flowers of certain living plants, especially those yellow or red colour, as *Calendula officinalis, Tropæolum majus, Helianthus*

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Papaver orientale, have been observed to emit a sudden flashing light on fine summer evenings, a little after sunset. Some plants also emit in the dark a faint continuous light, probably arising from the combustion of some substance, such as a hydrocarbon, emitted from them; this phenomenon has been observed in the leaves of *Phytolacca decandra*, which shine at night, sometimes with bluish-green, sometimes with yellowish-green light. The acrid milky juice of *Cipo de Cananum* (a Brazilian plant, probably of the euphorbiaceous order) emits light for several hours, after flowing from a wound in the plant. *Rhizomorpha subterranea*, a plant which grows in mines, emits light from its whole surface, but especially from the whitish growing points, and a similar phenomenon has been observed in other subterranean plants.

A more familiar kind of phosphorescence is that exhibited by many living animals, as by the glow-worm and fire-fly, and the numberless small marine animals, such as crustacea, medusæ, polypora, and infusoria, which give rise to the phosphorescence of the sea at night. In many animals the phosphorescence is an act of the will; in others it takes place at a particular period of life.

In nearly all phosphorescent plants and animals, the phosphorescence appears to be due to chemical action, in fact to a slow combustion: for it increases in brightness in pure oxygen gas, and ceases altogether in a vacuum or in nitrogen or carbonic acid gas; the phosphorescence of decaying fish, however, takes place in nitrogen as well as in air or oxygen.

Phosphorescence may be excited artificially in a large number of bodies by any cause which sets their particles in rapid vibration; viz., by *heat*, by the *electric discharge*, by *mechanical action*, and by *insolation*.

1. Many solid bodies become phosphorescent when thrown upon a heated surface; such is the case with diamond, chalk, certain varieties of fluor-spar, oyster-shells, paper, flour, especially that of maize, and indeed with most well-dried organic substances. This effect is not to be confounded with incandescence, for it takes place at temperatures much below an ordinary red heat; and the light emitted is generally of a blue or violet tint, instead of the dull red of incipient incandescence.

2. A lump of sugar through which a powerful electric discharge is passed, shines for several seconds afterwards with a beautiful violet light; and a similar effect is produced on many non-conducting minerals, but not on metals or other substances of good conducting power. Substances which have lost the faculty of becoming phosphorescent by heat or by insolation, recover it after they have been subjected to repeated electric discharges. There can be but little doubt that the immediate effect of the discharge is to throw the particles of the body into a state of rapid vibration, which is then communicated to the surrounding ethereal medium.

3. The phosphorescence produced by friction, percussion, and other mechanical actions, generally lasts only as long as the disturbing cause continues to act. In many cases a development of electricity takes place at the same time, and to this the light may be partly or in some cases wholly due; sometimes, however, the light emitted appears to be a direct consequence of the vibratory motion communicated to the particles by the mechanical disturbance. Adularia struck with a hammer so as to split it, emits at each crack a light which may last for several minutes; and when ground in a mortar, it appears all on fire. Quartz, fluor-spar, rock-salt, and sugar likewise exhibit light when broken or pounded.

Light is often emitted during the change of state of bodies, especially in the passage from the amorphous to the crystalline state, and the separation of crystals from a solution (i. 200).

4. *Insolation*, or exposure to the sun's rays, develops phosphorescence most easily in substances which are bad conductors of heat. Most calcareous substances are capable of becoming phosphorescent by insolation: *e. g.* carbonate and sulphate of calcium, fluor-spar, petrifactions, shells, and pearls.

Canton's phosphorus, prepared by heating calcined oyster-shells with sulphur, emits after insolation a yellow light bright enough to show the time by a watch. The phosphorescence may even be excited by exposure to the light of a candle. The *Bolognian phosphorus*, prepared by strongly igniting heavy spar with gum-tragacanth, emits, after insolation, a bright light which lasts for more than a day. *Baudoin's phosphorus* (fused nitrate of calcium) emits a white light. Diamonds sometimes remain phosphorescent for an hour, after exposure to the sun for a few seconds only. Certain organic substances, *e. g.* flour, sugar, gum, white wax, and resin, also shine after insolation.

From recent researches by E. Becquerel, it appears that the number of bodies rendered phosphorescent by insolation, is much larger than has hitherto been supposed, phosphorescence, lasting for a few seconds, or rarely for a few minutes, being exhibited by numerous minerals and salts, chiefly with alkaline or earthy bases. (See *Daguin's Traité de Physique*, iv. 250.)

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For numerous details relating to phosphorescence, see *Gmelin*
(i. 181—209).

The Electric Light.—The passage of electricity, when it meets with a
ance, is accompanied by light, more or less bright in proportion to the st
charge and the degree of resistance. As the discharge in all cases, eve
highly rarefied atmospheres, such as Gassiot's tubes (ii. 391), takes place
medium of material particles, we may suppose in this case also that the
origin to vibrations excited in these particles by the electric action.

Radiation.

To understand the manner in which the vibrations of luminous bodi
mitted in waves or undulations through the surrounding ether, it will be
consider shortly the nature of undulations in general. A *wave* or *u*
a disturbance excited in one part of a body, and communicated to the o
regular succession. For example, a stone thrown into water depresses
the part where it is thrown in; the portion so depressed exerts a latera
those immediately surrounding it; and these again exert an upward pre
particles external to them, and form a raised circle; afterwards these port
in falling, push up other particles, situated external to them, and thus th
continually spreads outwards in concentric circles till it extends to the who
the liquid. Now it is important to notice that these particles have no
motion; they merely move up and down, as may be seen by observing t
a light body floating on them: there is an appearance of progressive moti
only an appearance, arising from the same form or state of motion being
communicated to the different parts of the liquid. The wave travels onwa
for miles, or, as in the case of the ocean tide-wave, all round the glo
individual particles of water merely move in vertical lines through spaces
ing a few feet. Again, in the case of the waves in air which produce
individual particles of air merely move backwards and forwards through sm
the motion being first excited in the particles immediately in contact with t
body, afterwards communicated by these to the next, and so on, and this
tion of the vibratory motion from particle to particle constitutes a wa
Here again the progress of the wave must be carefully distinguished from
of the individual particles. Sound travels through the air at the rate of
feet in a second; now if the individual particles of air whose vibration p
sound were to rush onwards at that rate, every sound would be accompani
turbance of the air amounting to a hurricane.

Thus it is also in the case of light. The motions of the individual part
ether take place through immeasurably small spaces, but are commun
immense rapidity to the next; from these to those beyond them, and
through the vast distances between the heavenly bodies. So long as the et
which the light-wave travels is of uniform density—as we must suppose it t
space, and in media of uniform constitution, such as water, glass, and ot
tallised bodies—the wave spreads with equal velocity in all directions; co
all the particles to which the motion extends at the same instant are situ
surface of a sphere having the luminous body in its centre, and the illuminat
in lines at right angles to this wave-surface, that is to say, in straight lin
from the luminous body: these lines are called rays of light. When an
density takes place in the medium, the wave-surface is no longer perfectly sp
the rays are broken or curved according as the change of density is sudden

The vibrations of the particles of an elastic medium may be of two kinds
or *longitudinal*, when the line of vibration coincides with, or is parallel to, t
in which the wave travels onwards, as in the case of sound-waves in air.—2.
or *normal*, when the particles vibrate in directions at right angles to the m
wave, as is the case with waves in water, and with the vibrations of a stre
set in motion by drawing a bow across it.

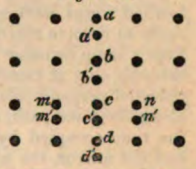
Suppose a particle of an elastic medium to be disturbed in any direction
This direction will in general be oblique to the line joining this particle wi
and the actual velocity of the particle may be resolved into three others,
direction of the line of junction between the two particles, that is to
direction in which the wave-motion proceeds, the other two in a plane at r
to it. The first component determines the longitudinal, the other two
motion or vibration of the particle; and the relative distances to which thes
of vibration are propagated depends upon the peculiar constitution of th
When the air is set in motion by the vibrations of a sounding body, it i
tudinal vibrations which travel onwards, producing a series of compre

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e of the wave, and these motions ultimately reaching
d: the lateral vibrations, on the other hand, appear
l events, they produce no effect upon the ear. With
ether, however, the case is exactly reversed; for, as
ena of polarised light show plainly that the transverse
y ones which affect our visual organs. With regard
particular directions of the vibrating particles may

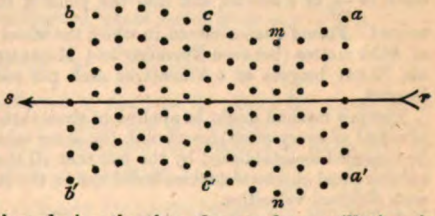
de of transmission of the transverse vibrations of the
w of these particles, *a*, *b*, *c*, *d* (*fig.* 640), situated in a
by any disturbing force into
of the forces which hold the
ws in their places will then be
lf is small in comparison with
les, the forces at right angles
remain unaltered; but the
the direction of displacement
n *n* is diminished. The same
all the particles in the same
oon move in the same direc-

Fig. 640.



of particles is, however, urged back to its original
at with which it set the other particles in motion;
direction is gradually destroyed, and it returns to
er, it passes beyond, in consequence of the momentum
orming a succession of small oscillations like those
ons are performed successively by the second, third,
if by the time that the first row of particles, *a a'*
oscillation, backwards and forwards, the vibratory

Fig. 641.



ibrium during the time of a complete oscillation, is
ration. It is proportional to the greatest velocity of
rough its position of equilibrium. The intensity of
viva of the vibratory particles, and therefore to the
ration.

e at which a wave travels through an elastic medium
density, and when these are known, as in the case of
ay be calculated *a priori*, by the formula $v = \sqrt{\frac{e}{d}}$
light, these elements are unknown, and therefore
d by observation. The following methods have been

s of Jupiter's Satellites.—This method was proposed
onomer Römer in 1676. He found that, when the
piter, that is to say, at its least distance from that
r moons enters the shadow of the planet at intervals
from this the time at which the 100th eclipse should
retardation of 15 minutes behind the calculated
ne earth had travelled about half round its orbit, and
ce from Jupiter by nearly half the diameter of that
ce which the light from Jupiter had passed over in
y of light was found to be 77,000 leagues, or 167,600
At this rate it takes 8′ 13″ to reach us from the sun,
0 years from the nearest fixed star (61 *Cygni*).

d Stars.—The motion of the earth in its orbit, com-
g from the stars, causes them to appear, not in their

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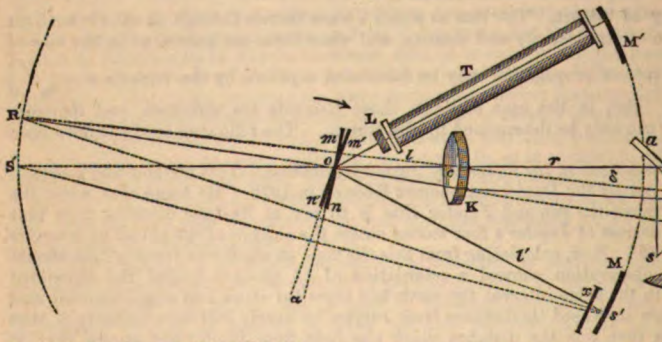
true places, but in the direction of the resultant of these two motions. Th positions of all the stars are, accordingly, shifted in the direction in which t moving. Each star, in the course of the earth's annual revolution, describ ellipse round its true place; for a star in the pole of the ecliptic, this ellip a circle of 20·445″ apparent diameter. The tangent of this angle gives the ra the velocity of light and that of the earth in its orbit; and the latter being independent observation, the velocity of light is thence found to be 166,072 g miles per second, a result differing from that of Römer by less than 1 pe must also be observed that Römer's method gives the velocity of reflected l space, whereas the aberration method gives the velocity of direct light in a

3. *Measurement of the velocity of light by small distances.*—α. *Fizeau's* toothed wheel having its teeth of the same width as the intervals betwe made to revolve rapidly, so that its teeth may pass through a beam of light from a lamp or other source, the light being thus intercepted by the teeth, through only at intervals. The light which passes between the teeth of t reflected perpendicularly from a plane mirror placed at a great distance; it t along the same path, and again passes between the teeth of the wheel. N the time occupied by the light in travelling twice over the space betwee and the mirror, the wheel will have performed a certain part of its revolut it turns with a due degree of velocity, the light which has passed in the fi between two of the teeth will strike, at its return, on the face of a tooth i space between two teeth, so that an observer looking through the wheel in t of the mirror, will not, in that case, perceive any light. The time whic takes to pass from the wheel to the mirror and return, is therefore equal which a tooth of the wheel moves into the place previously occupied b immediately preceding it, which time is easily calculated from the known the wheel and the number of its teeth. If, for example, the wheel has s makes t revolutions per second, each tooth will pass into the place of th tooth in $\frac{1}{n\,t}$ of a second, and into the place of the space next preceding, second. Fizeau's experiments, in which the wheel and mirror were placed a of 8633 metres (between Turesnes and Montmartre), gave, as the velocity air, 78,841 leagues of 4 kilometres each per second. Römer's method g leagues.

Fizeau's method might be applied to show that rays of light of all colours of sound of every pitch) travel with the same velocity. This conclusion ma be regarded as established by the fact that all the stars, whatever may be t exhibit equal aberration, which could not be the case if rays of different colo with different velocities.

β. *By means of a Revolving Mirror.*—This method, proposed by Arago, out independently by Foucault, and by Fizeau and Breguet, is similar in that by which Wheatstone determined the velocity of electricity, and afford

Fig. 642.



of measuring the velocity of light in a space not exceeding four metres. A li S (*fig.* 642), proceeding from a very narrow rectangular aperture at right an plane of the figure, after passing through the converging achromatic lens K, w form an image of it at S′, falls upon a plane mirror, *mn*, capable of revolving o axis passing through *o* on the line S S′, which reflects it to *s*′, a point symmetri as regards the mirror. At this point is placed a concave spherical mirror

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centre of figure is in o. The light falling on this mirror is reflected back again along the same path, $s'o$, to the plane mirror, mn, which again reflects it to S in a beam coinciding with the incident light. This will be the case in all positions of the mirror mn, provided the light is reflected from it to M. As the image thus sent back to S would be confounded with the incident beam, an unsilvered plate of glass, ab, is placed in such a position, that the light falling upon it in the direction oS may be partly reflected to s, where it may be observed by an eye-piece furnished with a vertical wire. If the mirror mn be made to revolve slowly, an eye placed at s will see the image of the line of light at intervals, but if the mirror makes more than 10 turns in a second, the image will be seen continuously; and if the eye-piece be adjusted, so that the image shall coincide with the wire, when the mirror makes from 20 to 30 revolutions per second, it will be seen to deviate in the direction of the rotation when the rate is increased to several hundred turns per second; if, for example, the mirror turns in the direction of the arrow, the image will be displaced from S to R, or from s to r. The cause of the displacement is that the mirror mn has time to revolve through a sensible angle, during the time occupied by the light in travelling from o to s' and from s' to o, so that the beam of light, at its second reflection from mn, is deflected from its first direction, forming, with the incident beam So, an angle equal to twice the angular displacement of the mirror.

The mode of calculating the velocity of light from the observed deviation is as follows:—Let $Sc = r$; $co = l$; $os' = l'$; the arc of deviation SR or $sr = d$; also let n be the number of turns performed by the mirror mn in a second, and V the velocity of the light. The mirror mn having moved into the position $m'n'$, by the time that the ray reflected from M returns to it, the deviation would be equal to the angle SoR, if the ray were not deflected by the lens cK, or, which comes to the same thing, if the point c coincided with o. Suppose, first, that this is the case; then the angle SoR is equal to twice the angle α, through which the mirror revolves during the time occupied by the light in passing over the space $2os' = 2l'$. This time is $\frac{2l'}{V}$, and since the mirror makes n turns in a second, the angle $\alpha = \frac{2nl'}{V}$. The angle of deflection of the ray is therefore $\frac{4nl'}{V}$, and the corresponding arc, whose radius is $oS = r + l$, is

$$d = 2\alpha . 2\pi . \frac{\overline{oS}}{} = \frac{8\pi nl'(r+l)}{V}.$$

But the reflected ray is actually deflected by the lens K. Draw R'c through the optic centre c and the point R', which is the image of s' in the mirror $m'n'$. The image of R', formed by the lens K, will then be at E, and the angle of deviation will be $ScE = \delta$. Now the triangles $oR'S'$, $cR'S'$, give $\sin R'cS' = \sin \delta = \frac{R'S'}{S'c} = \frac{R'S'}{l+l'}$; and $\sin R'oS' = \sin 2\alpha = \frac{R'S'}{l'}$. Hence, replacing the angles (which are very small) by their sines, and substituting for 2α its value $\frac{4nl'}{V}$, we find $\delta = \frac{4nl'^2}{V(l+l')}$; and for the arc $SE = D = 2\pi r\delta$:

$$D = \frac{8\pi l'^2 nr}{V(l+l')}; \text{ whence } V = \frac{8\pi l'^2 nr}{D(l+l')},$$

a formula which gives the velocity of light as a function of the deviation.

The same method serves also to measure the velocity of light in water or any other liquid, a tube T containing the liquid, and closed at the ends with flat glass plates, being interposed between the mirror mn and M'. As, however, the light would be refracted by the liquid, and therefore the focus would not fall on M', a diverging lens is placed at L to compensate for the deviation thence arising.

Moreover, as the column of water does not occupy the entire space between the mirrors, the velocity calculated as above from the observed deviation is only the mean velocity of light in a space occupied partly by water and partly by air. Let U be this mean velocity; w and a the spaces occupied by the water and air respectively; V' and V the corresponding real velocities. The times occupied by the light in traversing the spaces a and w are $\frac{a}{V}$ and $\frac{w}{V'}$, and the whole time is $\frac{aV' + wV}{VV'}$. Hence, dividing the total space $a + w$ by the time, we find for the mean velocity:

$$U = \frac{VV'(a+w)}{aV' + wV},$$

whence

$$V' = \frac{wUV}{(a+w)V - aU}$$

By this method it is found that the velocity of light in water is less than in air, a

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result which, as will be seen hereafter, is in accordance with the wave-t
it is directly opposed to that which would follow from the theory of emiss

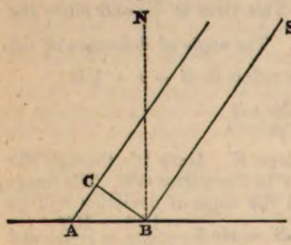
Intensity of Light. The intensity of the light received by a surfa
given source—that is to say, the quantity of light received by a unit of t
depends partly on its distance from that source, partly on the obliquity
light falls upon it.

1. *The intensity of light emanating from a point varies inversely as t
the distance.* For, as the undulations excited by the luminous source
equal velocity in all directions—supposing the medium uniform—they
garded as spreading out in concentric spherical surfaces of continuall
magnitude; and as these surfaces are to one another as the squares of t
follows that the quantity of light received by a unit of surface will vary
the square of the radius of the sphere of which it forms a part—that is t
square of its distance from the luminous point.

If the luminous body is of finite dimensions, the preceding law, being
the light emanating from each point of its surface, must likewise hol
regard to the whole, provided the body is sufficiently distant to admit of
being regarded as equally distant from the illumined surface; and since
diameter varies inversely as the distance, *the intensity of the light will v
proportion to the square of the apparent diameter* or to the *apparent su*
luminous body, understanding by this last term the conical angle of a c
ing the body and having its vertex at the luminous point.

2. *The intensity of the light received by any surface varies as the cosine
which the incident rays make with the normal to that surface.* For
(*fig.* 643) to be a portion of the illuminated surface, so small that the
upon it may be regarded as parallel.

Fig. 643.



tity of light received by A B, is the s
which would fall on its projection B C
perpendicular to the direction of the ray
fore exposed to their full effect; hence
of the light falling on these two surfaces i
their areas; but B C = A B. cos A B C = A
the angle which the incident rays ma
normal B N.

3. *The intensity of the light emanating
luminous surface, is proportional to the
angle which the rays make with the no*
proportion may be demonstrated in a sir
to the preceding, and the result may
by looking through a small aperture at an incandescent surface, as tha
iron, and inclining it more and more to the direction of the rays proceedi
the eye. In accordance with this law, it is found that the brightness of
surface is independent of its form and of its position with regard to the
the impression produced by it on the eye being the same as that produce
surface of equal intrinsic lustre, which is the projection of the original
plane perpendicular to the visual rays: a red-hot ball, for example, seen fro
looks just like a flat disc.

Comparison of the Intensity of two Luminous Sources: PHOTOMET

The eye is not capable of judging directly, with any great approach to
the relative intensity of two lights, but it can perceive with great nicety
contiguous surfaces or portions of the same surface are equally illuminated
two contiguous shadows have or have not the same depth. On this princi
structed most of the instruments called *Photometers*, for measuring the re
sity of different sources of light.

Rumford's *Photometer*, which is very easily constructed, consists
wooden cylinder set upright in front of a sheet of white paper, also place
The two lights to be compared (a candle and gas-flame, for example) are p
same height in front of the paper, and in such a manner that the two sha
wooden cylinder which they cast, shall fall on the paper close together, a
rays from both of them shall meet the paper at the same angle. Each
then be illuminated by only one of the lights, while the rest of the surface
the rays from both, and the two shadows will be of the same depth when
of the paper is equally illuminated by both lights. If then the strong
moved farther off till the shadows are equally dark, the intensities of the
directly as the squares of their distances from the screen when that cond
filled.

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This photometer gives very exact results in many cases; but in applying it to determine the relative illuminating power of a gas-flame and a candle, a difficulty arises from the different colours of the two shadows, that of the gas being bluish-brown, while that of the candle is yellowish-brown. In all such cases, Bunsen's photometer, whose indications do not depend on depth of shadow, is much more convenient.

Bunsen's *Photometer* consists of a screen of thin writing paper stretched on a frame, and saturated with a solution of spermaceti in oil of turpentine, except a spot in the centre about the size of a shilling. A light of constant intensity being placed at a fixed distance behind the screen, the ungreased spot appears darker than the rest of the screen. One of the lights to be compared is then placed in front of the screen, so that its reflected rays may be added to the light transmitted from behind, and adjusted so that the ungreased spot shall be illuminated just as much as the rest of the surface, and shall therefore be no longer visible. This will be the case when $T + r = t + R$, denoting by T, t, the quantities of light transmitted by the uncovered part of the screen, and the part covered by the disc respectively, and by R, r, the quantities reflected. A precisely similar experiment being then made with the other source of light, the intensities of the two will be to one another as the squares of their distance from the screen at which the disappearance of the disc takes place. Sometimes the grease is applied only to a small circular spot in the centre of the screen, which then transmits more light than the rest of the surface.

Masson's *Electro-photometer*. This apparatus has the advantage of admitting of the comparison of lights of different colours. It consists of a circular disc divided into white and black sectors of equal size, and set in motion by clock-work at a uniform rate of 250 to 300 revolutions in a second. If it be then illuminated by a constant source of light, such as a lamp, it appears of a uniform grey tint, in consequence of the duration of the visual impression on the eye. But if it be illuminated by an instantaneous light, such as the electric spark, the black and white sectors become distinctly visible, and appear as if they were fixed, because they have not time to move through a sensible angle during the extremely short interval for which the spark continues. If now the intensity of the light afforded by the spark be gradually diminished, as by removing it to a greater distance, the source of constant light still remaining, the increase of illumination which the spark affords to the disc ultimately becomes too feeble to render the sectors visible, so that the disc still continues to exhibit a uniform grey tint. The relative intensities of the constant and instantaneous lights at which this limit is attained, evidently depend upon the number of the sectors and the velocity of revolution.

The relative intensities of two electric sparks are as the squares of the distances to which they must be removed from the disc to cause the sectors to disappear, while the disc is illuminated by a constant light. On the other hand, to use the instrument for comparing the intensities of two continuous lights, a succession of electric sparks is made to pass in front of the disc, and one of the constant lights is made to approach it till the sectors cease to be distinguishable. The same experiment being then made with the other light, the intensities of the two are as the squares of the distances thus determined.

By means of this instrument, M. Masson has demonstrated the following laws relating to the intensity of the electric light. 1. *It is proportional to the coated surfaces by the discharge of which, at a constant distance, the spark is produced.* 2. *It is inversely as the distance between those surfaces, or as the thickness of the jar.* 3. *It is proportional to the square of the striking distance.* 4. *The quantities of light in the spark are proportional to the quantities of heat developed in a wire forming part of the same circuit.*

General results of photometric observation.—1. By comparing the quantities of light emitted by the same number of flames in different relative positions, it is found that flame is perfectly transparent; in fact the luminous effect of a series of candles placed side by side, is the same whether they are arranged in a line perpendicular or parallel to the direction of the rays. In like manner, a flat gas-flame, like that of a bat's-wing burner, gives the same amount of light in all directions.

2. It appears from observations by Bouguer, made with Rumford's photometer, that one of the shadows thrown by lights of equal brightness disappears when one of these lights is placed 8 times as far from the screen as the other—that is to say, when the nearer light illuminates the screen 64 times as strongly as the other. Hence it appears that light emanating from any source becomes imperceptible in presence of another 64 times as strong; the disappearance of the stars in daylight shows, therefore, that the diffused light of the earth's atmosphere must be at least 64 times as strong as that sent to us from any of the stars.

3. When the flames of two lamps or candles touch one another, the intensity of the

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combined flame is greater than the sum of the intensities of the separate fla effect, first observed by Franklin, appears to be due to the increased tem the part where the flames overlap. Rumford found that a number of flat c impregnated with oil, gave a much greater amount of light when they w together nearly in contact, than when they were separated. On the sam Arago and Fresnel have constructed lamps for light-houses, in which a concentric wicks are arranged with small spaces between them, through w rent of air is made to pass by the draught of a chimney. The flame being t a considerable amount of light is thus obtained within a small space.

4. The photometric method serves also to determine the illuminating eq different light-giving materials. Rumford found that 100 pounds of wax b form of a taper, were equal in light-giving power to 101 lbs. of tallow, if were well snuffed, and 229 lbs. if the wicks were allowed to grow long; of olive oil burnt in an Argand lamp, and 129 in a lamp burning with also to 125 lbs. of rape oil, and 120 lbs. of linseed oil in a common lam calculated the following table of the expense per hour of various modes of il yielding a quantity of light equal to that afforded by a gas-jet burning at 5 centimes per hour:

	Centimes.		
Carcel lamp	5·8	Wax taper of 100 grm. . .	
Candle of 82 grm. . . .	9·8	Stearine candle . . .	
Candle of 10 grm. . . .	12·0		

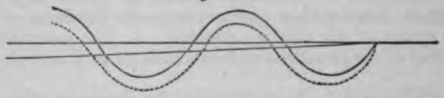
It appears from this comparison that gas is the most economical of all i materials. The results depend, however, in a great measure on the facili of air to the flame, the form of the wick or burner, and the length of the numerous determinations of the illuminating equivalents of various kinds other light-giving substances, see *Ure's Dict. of Arts, &c.*, articles Coal- and Illumination (ii. 493).

Interference.

When two or more waves pass over the same part of a medium, each of t the particles of the medium disturbed by the other just as it would have affect particles in a state of rest. Consequently, the state of any particle affected waves at once, will be the same as that which would have resulted if it ha disturbed by the one wave, and then the second had acted upon it while i turbed state. Thus the height of the tide is found by calculating the heigh it would be raised by the sun and by the moon acting separately, and taki or difference as the case may be.

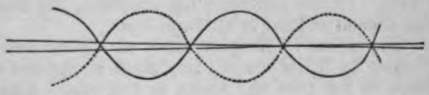
Suppose now two waves of equal breadth and intensity (equal height in water) to proceed from the same, or nearly the same point, and travel o after the other; then, if they meet in such a manner that the phases or alt the one coincide with the phases or alternations of the other, the result wil pound wave, having the sum of the intensities of the separate waves; this case if the paths along which they travel before meeting are of equal lengt exceeds the other by any exact number of whole undulations, as in *fig.* 644 phases of the one are exactly opposed to the phases of the other, which

Fig. 644.



when the one wave is behind the other by any odd number of half-undula *fig.* 645, a wave will be produced whose intensity equals the difference of the

Fig. 645.



of the separate waves, and if these are equal, the vibratory motion will be destroyed and the particles of the medium brought to rest along the whole combined waves. If the paths of the two waves do not differ by any exact half undulations, even or odd, the result will be intermediate between th considered, the intensity of the combined wave being always less than th

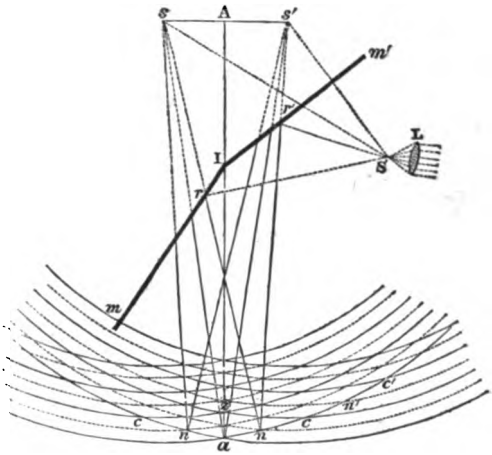
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greater than the difference of the separate waves. This composition or superposition of oscillations is called Interference. In order that it may take place along a whole line of wave, it is clear that the component waves must be of the same breadth, and that they must proceed from points very near each other, otherwise their paths will intersect only at isolated points.

Let us now enquire whether these principles are applicable in the case of light. If light consists of undulations, and these undulations are governed by ordinary mechanical laws, it must follow that two rays of light may meet one another in such a manner as to counteract each other's action and produce darkness; and such, in fact, is found to be the case.

Suppose s, s' (*fig.* 646) to be two radiant points very close together, and producing in the luminiferous ether, waves of the same length (of red light, for example) and always in the same phase of vibration at the instant of starting from these points. Imagine also two series of spherical wave-surfaces having the points s, s' for centres, and with radii increasing successively by half the length of a wave $= \frac{\lambda}{2}$. These surfaces will cut the plane of the figure in two systems of arcs, which will intersect one another in the manner shown in the figure, in which each two consecutive arcs, one represented by a full, the other by a dotted line, are separated by the interval $\frac{\lambda}{2}$, and each pair of alternate arcs (both full or both dotted) by the interval λ, or a whole undulation.

Fig. 646.



Consider now the point a, situated on the line Aa, drawn perpendicular to ss', through its middle point A. The two rays sa, $s'a$, being of equal length, are in the same phase of vibration: consequently their intensities will be added to one another and will produce increased light, and the same effect will be produced at c, c', and at all the intersections of the continuous arcs, where the difference in length of the rays proceeding from the points s, s' is equal to any multiple of λ or to any even multiple of $\frac{\lambda}{2}$. But at n, n' or any other intersections of a continuous and a dotted arc, where the difference in length of the rays sn, $s'n$, &c., is equal to $\frac{\lambda}{2}$, or any odd multiple thereof, the rays are in opposite phases, so that their vibrations act against one another, and the amount of light at those points is less than it would be if only one of the rays arrived there. The distance between the points s, s' being very small compared with Aa, the surface anc is very nearly plane, so, that if a white screen be placed there, a succession of luminous points, a, c, c', &c., will be formed upon it separated by dark spaces, n, n', &c.

If the sources s, s', instead of being luminous points, are lines of light perpendicular to the plane of the figure, a series of alternate light and dark bands, or fringes, will be produced parallel to those lines.

The conditions essential for exhibiting these effects are, that the two luminous sources s, s' shall be very near one another, and that the waves emanating from them shall always be simultaneously in the same phase. These conditions are most easily fulfilled by the following arrangement devised by Fresnel:—

A beam of light entering through a rectangular slit in the shutter of a darkened room, and passing through a plate of red glass, is condensed at S to a very fine line of light, by a cylindrical lens L (*fig.* 646) of very short focus. The rays there cross each other, and fall upon two plane mirrors Im, Im', placed together at a very obtuse angle, and having their line of intersection parallel to the line of light. The rays, after reflection from these mirrors, proceed as if they had originally issued from two points s, s', situated symmetrically to the point S, behind each of the mirrors. The mirrors being

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placed nearly in one plane, the points s s' are very close together, so that all the conditions are fulfilled for the production of light and dark fringes on the screen, as above described.

Instead of reflecting the light diverging from S from two plane mirrors, it may be made to pass through a glass prism having a very large refracting angle. The fringes also, instead of being received on a screen, may be viewed through a telescope, and their angular breadths estimated by micrometrical measurement.

If the beam of light proceeding from one of the points s, s', be intercepted, the whole of the fringes disappear, and the light from the other source produces a uniform illumination on the screen, plainly showing that the fringes are produced by the combination or interference of the rays proceeding from the two sources.

Measurement of the lengths of the waves of light.—The breadths of the fringes having been ascertained, as above described, an easy calculation gives the lengths of the waves of the particular light by which they are produced. In *fig.* 646, the length of the wave λ is equal to the distance sa. Now the curvilinear triangle asc may be regarded as a right-angled triangle, whose hypothenuse $ac = b$ is the distance from the centre to the first bright lateral fringe. Moreover, the angles sca and sas' = ω are equal, because their sides are respectively perpendicular to one another: hence

$$\lambda = b \sin \omega.$$

Hence to obtain the value of λ, it is sufficient to measure the angle sas' with a repeating circle, and the distance ac with a micrometer. A more exact mode of determination will be described hereafter.

The length λ is proportional to the distance ac. Now the breadth of the fringes is found to be greatest in red and least in violet light, and of intermediate breadths for the intermediate colours of the spectrum: hence also it follows that *the lengths of the waves are greatest in red and least in violet light.*

The formula $\lambda = \frac{v}{n}$, in which v is the velocity of light, and n the number of vibrations per second, shows that the vibrations are most rapid in violet, and least rapid in red light.

The length of the wave and the rapidity of vibration of the particles of the ether determine the colour of the light, just as the length of the sound-wave and the rate of vibrations of the particles of the air, determine the pitch of sound.

The following table exhibits the wave-lengths and the number of vibrations per second of the mean rays of the several colours of the spectrum, and of the principal fixed lines:

Fixed lines and colours.	Values of λ in ten-thousandths of a millimetre.	Number of vibrations per second in millions of millions.	Fixed lines and colours.	Values of λ in ten-thousandths of a millimetre.	Number of vibrations per second in millions of millions.
Line B . .	6·88	. .	Mean green .	5·12	601
Line C . .	6·56	. .	Line F . .	4·84	
Mean red .	6·20	497	Mean blue .	4·75	648
Line D . .	5·89	. .	Mean indigo .	4·49	686
Mean orange .	5·83	528	Line G . .	4·29	
Mean yellow .	5·51	529	Mean violet .	4·23	728
Line E . .	5·26	. .	Line H . .	3·93	

The expression $b = \frac{\lambda}{\sin \omega}$, which gives the breadth of the fringes in terms of the wave-length and the angle ω, shows that for each colour they are broader in proportion as that angle is smaller. If it is too large, that is, if the distance $s\,s'$ is too great in proportion to $A\,a$, the fringes disappear altogether; they are still visible, however, when this angle has a magnitude of several degrees.

The fringes being of different breadths in the different coloured lights, and white light, as will hereafter be shown, being a mixture of all the colours of the spectrum, it follows that when the preceding experiment is made with white light (sun-light, the electric light, or the lime-light), the bands produced are not simply bright and dark alternately, but exhibit a succession of colours produced by the combination of the simple colours in various proportions, and not separated by any absolutely dark bands. Moreover, these coloured fringes are much less numerous than the simple light and dark bands produced by homogeneous light, because the breadths of the simple-coloured fringes of which they are composed do not vary proportionally to one another, as their distance from the centre increases; hence, they ultimately become

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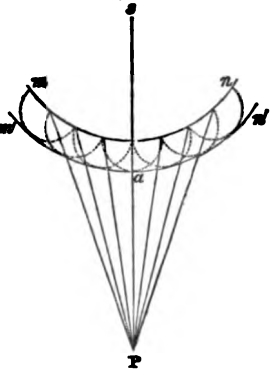
mixed, and reproduce white light. Even the simple fringes formed in homogeneous light become less and less distinct as they recede from the centre, and ultimately disappear when the difference between the lengths of the rays which form them becomes equal to a certain number of half-undulations. The cause of this disappearance is, that the light used in the experiment is never absolutely homogeneous, and that the want of perfect equality between the lengths of the waves which compose it, ultimately makes itself perceptible, the fringes of different breadths overlapping and effacing each other in the same manner as when white light is used, though at a much greater distance from the centre. Whatever kind of light is employed, the fringes are more distinct and numerous in proportion as the line of light is narrower, provided it be wide enough to give the required amount of illumination; for it is evident that a broad aperture may be regarded as a number of narrow ones placed side by side, each producing its own set of fringes, which, as they do not coincide in position, will overlap and efface each other more or less completely.

If a very thin plate of glass, mica, selenite, or other transparent substance be placed in front of one of the mirrors (*fig.* 646), so that the rays proceeding from one of the points, *s*, *s'*, shall be obliged to pass through it before reaching the screen or telescope, the whole of the fringes will be displaced towards the side on which the transparent plate is situated, so that the central fringe *a* will no longer be opposite to A. Suppose the displacement to be towards the right of the figure; then the line *s'a* will be shorter than *sa*. Now, as the two rays forming this central fringe must contain the same number of wave-lengths, it follows that these wave-lengths are less in the more highly refracting substance (glass, &c.) than in the air. The velocity of the light is, therefore, diminished in the more highly refracting medium; and experiment shows that the retardation thus produced is greater as the refracting power is greater. This result is in accordance with the direct measurement of the velocity of light in air and water (p. 595), and likewise, as we shall presently see, with the law of refraction. Moreover, as the velocity of transmission of vibrations in an elastic medium is related to its elasticity and density by the equation $v^2 = \frac{e}{d}$, it follows also that the elasticity of the ether is least, or its density greatest, in the most highly refracting media.

The transparent plate used in the experiment just described must be extremely thin; otherwise the fringes will disappear altogether, just as if an opaque screen had been interposed. A thicker plate would, in fact, shift the fringes beyond the space in which the two systems of waves meet each other, namely, the space bounded by the two straight lines passing through *s*, *s'* and the intersection, I, of the mirrors.

Diffraction. The principle of interference serves to explain some very remarkable and beautiful phenomena which are observed when light passes by the edge of an opaque body, or through a small aperture. The effects thus produced consist in this, that the light bends to a certain extent within the geometric shadow bounded by straight lines drawn from the luminous point through the edges of the opaque body, just as a wave in water will turn the angle of a wall, or spread itself through a hole in any fixed obstacle. The result is the formation of a number of alternate bright and dark bands or coloured fringes, sometimes within the shadow, sometimes beyond it, sometimes in both places at once. These effects, formerly known as Inflection, but now called Diffraction, admit of complete explanation on the wave-theory of light, but are quite inexplicable on the theory of emission.

Fig. 647.



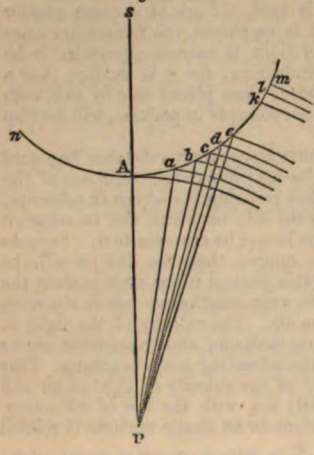
The explanation of diffraction on the undulatory theory depends upon the general principle first enunciated by Huyghens, that—*The vibrations of a wave of light, at each of its points, may be regarded as the resultant of the elementary movements which would be communicated to it, at the same instant, by all the parts of the same wave in any one of its previous positions.* For it is evident, from the elasticity of the ether, and the facility with which vibratory movements are transmitted through it, that its particles do not vibrate independently of each other, but that each may be regarded as a centre of disturbance with regard to all around it. Consequently, each point of a spherical wave, *mn* (*fig.* 647), will produce by its vibration, a number of secondary spherical waves, which, spreading out with the same rapidity, will have for their enveloping surface—that is to say, for the general surface of the wave as it spreads outwards—another spherical surface, *m'n'*, concentric with the former. Hence the vibration imparted to any point P, by the wave *mn*,

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when it reaches that point, may be regarded as the resultant of all disturbances emanating from the several points of *mn*.

To determine the manner in which the movement of P is affected points of the wave in any of its previous positions, draw *s*P, cutting the (*fig.* 648), and designating the distance AP by γ, describe, from P a with the radii γ, $\gamma + \frac{1}{2}\lambda$, $\gamma + 2.\frac{1}{2}\lambda$, a number of arcs cutting the wave *a*, *b*, *c*, *d*, . . . and draw the str Pb, Pc, &c., which evidently diffe by half a wave-length. Then it wi the intervals A*a*, *ab*, &c. are not tinually diminish from A toward for every point in *ab*, there exists such that the lines drawn from th differ by $\frac{1}{2}\lambda$, and consequently the w from these points to P will be in co ance. Hence, if A*a* were equal t on P would be completely neutrali this not being the case, *ab* can part of A*a*, and there remains a po A*a*, which produces a certain degr tion at P. There is a further reas tralises only part of A*a*, and that more obliquely. Similarly, *cd* w part, but only a part, of the action it will be seen that the illuminati P by the half-wave A*m* is the sum the arcs of uneven order over order, counting from A. In all ca

Fig. 648.



is only necessary to take account of that part of the wave which is v line *s*P: for at a greater distance, as at *m*, the arcs *kl*, *lm* become ve and, moreover, their action on P is very oblique—for both of whic effect on P may be neglected. The arc A*n* acts exactly like A*m*, illumination produced by A*m* be denoted by 1, that of the entire w equal to 2.

The arcs A*a*, *ab*, &c. are called elements of interference, and called the pole of the point P.

The direction of vibration of the ether-molecule P at any instant is that of the first element A*a*, of the half-wave A*m*; and if this portion w the point P would then vibrate in the direction determined by the n which is opposite to that of A*a*. Hence, it appears that the action of A*a* than the resultant actions of all the remaining elements, *ab*, *bc*, &c.: for changes its direction according as the element A*a* acts upon it or not, true with regard to each of the elements *ab*, *bc*, &c., the action of ea on P being greater than the resultant of all beyond it.

Now, suppose part of the half-wave A*m* to be intercepted by the int opaque screen; then the arc *ab*, which destroyed a great part of the removed, and the point P receives more light than it did before: for is greater than that of all the rest of the wave, from *b* outwards, ta Next suppose the screen to terminate at *b*; then, since *ab* destroys the A*a*, and the rest of the wave is intercepted, P will now receive less ligh if the screen were not there. In the same manner, it will be found th screen is so placed as to leave an odd number of elements of the wav P will be more illuminated than it would be if the screen were not contrary if an even number are left free.

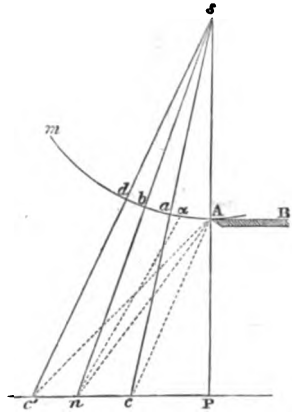
These principles lead immediately to the explanation of the phenome

1. *Fringes produced by rays passing along the edge of a screen.*—S of homogeneous light proceeding from a luminous point S (*fig.* 649) a fine line of light passing through S at right angles to the plane of th by the opaque screen AB, of indefinite extent towards B, and fall upon CD, covered with white paper. The boundary of the geometrical determined by the straight line SAP. The light received at P will p half-wave A*m*, and may be represented by 1; and from the preceding follows that the points *c*, *c'*, &c., so situated that $Ac - ac = \frac{1}{2}\lambda$; Ac' receive more light than if the screen were not there, and will therefor of bright fringes; and on the contrary, the points *n* *n'*, &c., for whi

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$As' - b'n' = 2\lambda$, &c., will receive less light than if the screen were away, and will therefore be the centres of dark fringes. The general result may be thus stated: The presence of a screen increases the intensity of the light at every point so situated that the broken line (SA, A*c* for example) passing to it from the source of light by the edge of the screen exceeds the straight line (S*c*) drawn to it directly from the luminous source, by an *odd* number of half undulations, and diminishes the intensity of the light at every point so situated, that the broken line (SA, A*n*) proceeding to it from the luminous point by the edge of the screen, exceeds the straight line joining it with the luminous point, by an *even* number of half-undulations.

Fig. 649.



In this manner, a succession of bright and dark fringes are produced beyond the geometrical shadow of AB; they may either be received on the screen CD, or viewed by a telescope directed to the edge A, the latter being of course the better method for exact measurement. They become less and less distinct as their distance from the edge of the shadow increases, because the successive arcs A*a*, *ab*, *bd*, &c. do not neutralise each other's action completely, so that a small quantity of light always mixes with the dark fringes, increasing in amount as they are more distant from P. Finally, at points situated so far from P that the portion of the half-wave intercepted by the screen is too far from the pole *b'* to produce a sensible effect, the fringes disappear altogether, and the surface of the screen becomes uniformly illuminated with light of intensity = 2.

The fringes are broadest in red, and narrowest in violet light; and in white light fringes of compound colours are formed, as in the experiment with the mirrors.

The locus of each fringe, light or dark, considered at different distances from the luminous source, is a hyperbola, having the points A, *s* for its foci. The dark fringe *n*, for example, of the *m*th order, gives $An - bn = m.\frac{1}{2}\lambda$; and subtracting these equal magnitudes from $sb = sA$, we have $sb - An + bn$, or $sn - An = sA - m.\frac{1}{2}\lambda$. The difference $sn - An$ is therefore constant, whatever may be the length of AP; consequently, the locus of the point *n* is a hyperbola whose foci are A and S.

There is also a certain quantity of light *within the geometrical shadow*. For any point *p* situated to the right of P (*fig.* 649) receives light from a certain portion of the wave A*ab*; but this portion is smaller and farther from the corresponding pole, as *p* is more remote from P: hence the brightness of the light diminishes rapidly from the edge of the shadow inwards; but the diminution is continuous and no fringes are produced.

Fringes at the edge of a Mirror.—Rays reflected from the edge of a plane mirror inclined to their direction, proceed as if they had originally issued from a line of light situated symmetrically behind the mirror. The space beyond the mirror may therefore be compared to the opaque screen in the experiment last described: hence the fringes are produced towards the surface of the mirror, whilst a continuous light is visible for a short distance beyond it.

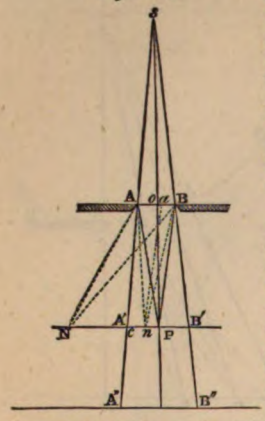
2. *Fringes produced by narrow rectangular apertures.*—Light passing through such an aperture may form fringes in the beam of light itself and in the shadow, separately or together, according to the width of the slit and the distance at which the fringes are viewed. They may be observed by means of a very simple apparatus, consisting of two thin plates of copper fixed in a small frame, one of them being capable of sliding backwards and forwards, so as to vary the width of the aperture at pleasure. On looking at the flame of a candle or other source of light through the slit, brilliant coloured fringes are seen parallel to the edges of the slit. These fringes are also very distinctly seen on viewing the flame of a candle between two fingers held up so as to leave a very narrow space between them.

Internal Fringes.—Let AB (*fig.* 650) be the slit, S the source of light, rendered homogeneous by passing through a coloured glass; and suppose in the first place that the screen A'B', on which the light is thrown, is placed at such a distance that $AP - oP$ and $BP - oP = \frac{1}{2}\lambda$; then all the points of the part AB of the wave-surface will be in accordance with each other, and there will be a bright band at P. The same will be the case *a fortiori*, if the screen A'B' is still farther removed, as to A"B". But if the screen be moved to a shorter distance from the slit, such that $AP - oP$ is

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more than $\frac{1}{2}\lambda$, and equal to n times $\frac{1}{2}\lambda$, then if n is even, each half of
may be divided into an even number of elements of interference,
destroy each other two by two. There
dark band at the central point P. If,
hand, n is odd, there will remain one
action is not neutralised, and the central
bright. Hence, as the screen is gradu
farther from the aperture, the central
alternately bright and dark, until the di
that $AP - oP = \frac{1}{2}\lambda$, at and beyond whi
always bright. The same alternations ma
by diminishing the width of the aperture
distance oP remains constant.

Fig. 650.



There are also fringes in the beam of lig
and left of P. Suppose that the distance
is such that the central band is bright, an
$\frac{1}{2}\lambda$, and let n be a point such that $Bn -$
The arc AB may then be divided in
$nB - na = na - nA = \frac{1}{2}\lambda$. The vibrations
to n by the two arcs An, nB will then
another to a great extent, so that there
band at n. At c, so situated that $cB - cA$
will be a bright band, because the arc
be divided into three elements of interfere

A precisely similar explanation applies to the case in which the central b

The interior fringes recede farther from the central point P, as th
the screen is greater in proportion to the width of the aperture; and wh
is placed at such a distance that $BA'' - AA'' = \frac{1}{2}\lambda$, the first dark band
and consequently there will be no fringes within the beam of light passi
aperture; the distance of the screen at which they cease to be produced
aperture is narrower.

External Fringes.—The mode of production of these fringes is similar
internal fringes just considered. Any point N, within the shadow on ei
be a centre of a dark or a bright band, according as NB – NA is equal
an odd number of times $\frac{1}{2}\lambda$. These external fringes rapidly lose their disti
recede from the edge of the geometric shadow, and disappear altogether
is so wide that the vibrations emitted from the point B are no longer s
For the simultaneous production of external and internal fringes, therefor
must be neither too wide nor too narrow.

The loci of both the external and internal fringes are hyperbolas ha
in A and B. All the fringes are broadest in red and narrowest in viole
white light are made up of bright bands of various colours.

3. *Fringes produced by two narrow slits very close together.*—The two
interfere and produce fringes, precisely as in Fresnel's experiment with
This, which is Young's form of the experiment, is similar to that by w
originally showed that light added to light may produce darkness.

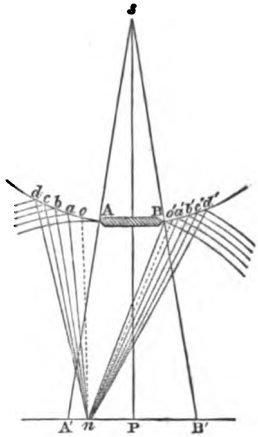
4. *Fringes produced by very narrow screens.*—In this case also fringes
both within and without the shadow. A hair or a thin wire held between t
flame of a candle or a bright line of light, exhibits these fringes very distin
that the screen A B, instead of being of indefinite extent towards B, as in
narrow that the light passing by each of its edges A, B (*fig.* 651), goe
middle of the geometric shadow A'B'; the rays will then act upon each
produce fringes within the shadow, independently of those beyond it.
also modified, because the points at which they are formed likewise rece
the opposite edge of the narrow screen, which contributes to their forma
on interposing an opaque body so as to cut off the light from one edge
the external fringes immediately alter their appearance, and the interna
pear altogether.

Formation of the internal fringes.—If the screen AB (*fig.* 651) is
narrow, the internal fringes differ but little from those which would
two slits placed at A and B; for the direction of vibration at any point
shadow is then determined by the action of the two elementary portio
immediately contiguous to A and B. When the screen is extremely nar
is the same, excepting that the effect of the first elements of interference
arcs Ad, Bd', being modified by the other portions of these waves, whic
tralise their action, the points, o, o', from which the resultant actions o

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may be considered as proceeding, are situated somewhat closer to A and B than they would be if the portions of the wave beyond *a* and *a'* were cut off. At any point *n* within the shadow, there will be a light or a dark band (in homogeneous light), according as $o'n - on$ is equal to an odd or even number of half-undulations. The point P in the middle of the geometric shadow, being perfectly symmetrical with regard to the arcs *Ad*, *Bd'*, receives from them accordant impulses, and is therefore the centre of a bright band.

Fig. 651.



The fringes are wider apart in proportion as AB is smaller, because in order, to obtain a given difference of length in the rays *on*, *on'*, the point *n* must then be taken farther from P. This may be verified by viewing a needle held parallel to a bright line of light; the fringes are then much broader near the point than near the eye.

5. *Fringes produced by screens or apertures which are very small in all directions.*—The effects in this case are much more complicated than in those above considered, where the edges of the screen or aperture are supposed to be straight, and so much elongated that it is sufficient to consider the effect of the cylindrical wave situated in a section at right angles to the screen or aperture. But in the case now under consideration it is necessary to consider the actions resulting from all the points of the free surface of the wave, and the problem becomes too complicated to be treated without the aid of the higher analysis. We shall therefore merely enumerate the effects produced in a few of the more simple cases.

When rays proceeding from a luminous point pass through *a small circular aperture* circular fringes are formed, both within and beyond the geometric image. The circular aperture may in fact be regarded as a number of very narrow rectilineal apertures radiating from the centre. In homogeneous light the rings are equidistant, and their diameters are inversely as that of the aperture, excepting that the distance from the centre to the first ring is less than that between two consecutive rings. The centre is bright or dark, according to the proportion between the size of the aperture and its distance from the screen, and either the external or internal rings may disappear according to these dimensions.

A small circular screen also produces fringes similar to those of the linear fringes formed by a narrow rectangular screen. At certain distances, the centre of the shadow is as bright as if the screen were not there.

A small rectangular aperture forms two series of fringes at right angles to its sides; their distances being inversely as the widths of the aperture in all directions. There is also a great number of small spectra, regularly distributed in the angular spaces formed by the two series of fringes.

Two small circular apertures placed at a certain distance from one another, form two series of rings just as if each of them existed alone; but if they are close enough to make the rings overlap, the rays proceeding from the two likewise produce, by their interference, a series of very close rectilineal fringes at right angles to the line joining the centres of the apertures, together with two sets of oblique fringes passing through the middle point between these centres. This is the original experiment of Grimaldi already referred to (p. 604).

6. *Diffraction through Gratings or Networks.*—When light, instead of passing through one or two small apertures, passes through a great number of them very close together and regularly distributed, some very remarkable diffraction phenomena are produced, which were discovered by Fraunhofer. Such a system of apertures is called in optical language a grating (*réseau*, Fr.; *Gitter*, Germ.).

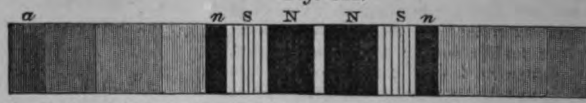
Fraunhofer formed his gratings:—1. By winding a very fine wire round two parallel screws of equal diameter and very fine thread.—2. By tracing very fine parallel lines on a film of gold-leaf fixed on a plate of glass.—3. By tracing lines with a diamond on a plate of glass, the lines thus formed being opaque, while the intermediate spaces are transparent. This is the method now generally adopted, a dividing engine being used to ensure regularity in the lines. Sometimes the lines are traced on glass covered with a thin coat of varnish, and etched with hydrofluoric acid. When great regularity is desired, the number of lines in a millimetre must not exceed 300, and 38 in that space are sufficient for the complete manifestation of the phenomena.

Effects of Parallel gratings.—A line of light viewed through a grating formed by parallel lines, appears just as it would to the naked eye, excepting that it is somewhat

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fainter; while on either side is seen a dark space N (*fig.* 652), followed
S, S, having the violet within, and its colours so pure that the principal

Fig. 652.

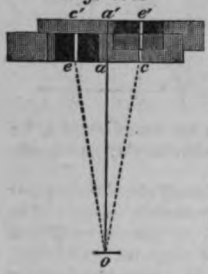


be easily distinguished in it. Then comes another dark space narro
former, then several other spectra more and more extended, but overlappi
more and more, so that their colours become paler and finally disa
spectra may however be separated by viewing them through a prism, t
then appearing. In homogeneous light, nothing is seen but isolated band
of the light employed, being in fact the corresponding portions of the se

Masson has observed that the electric light viewed through a grating e
lines, as when seen through a prism.

To measure the breadth of these spectra, the grating *o* is placed in
parallel slits *e*, *e'* (*fig.* 653), the distance between which admits of va

Fig. 653.



systems of spectra *ec*, *c'e'* are then seen, whi
superposed, but may be distinguished by placin
slits a little higher than the other. To find th
angle of deviation, of any given fixed line, the
separated, or the grating moved farther back, til
belonging to the right-hand spectrum formed
coincides with the same line *a'* in the left-hand
the same order formed by the slit *e'*. The angl
equal to twice the angle of deviation sought,

and the right-angled triangle *aeo* gives tan D = $\frac{a}{a}$

taking the angle for its tangent The angle of
therefore given by the distance between the sl
distance from the grating.

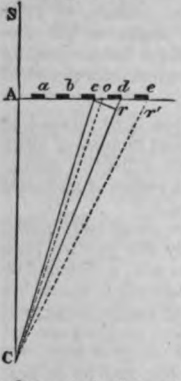
By observations thus made it is found that:—1
points of the successive spectra are equidistant, or in other words, the
these middle points are to one another as the numbers 1, 2, 3, 4, &c.

2. The lengths of the successive spectra, or the distances between two
responding fixed lines, are to one another as the same numbers.

3. The difference of thickness of the opaque and transparent lines has
on the position of the spectra, but merely modifies their brightness.

4. The lengths of the spectra depend upon the sum of the widths of ar
transparent space taken together; this sum is called an element of
The deviation of any given line is inversely as the distance between two
it is proportional to the number of elements in a millimetre. When th
100, the first spectrum has the same width as that produced by a flint-gl

Fig. 654.



60°. Moreover the spaces occupied by the severa
the spectra are sensibly equal, so that the spectrum
may be called a *normal spectrum*, and may serve a
of comparison for the irregular spectra produced by

The preceding laws may be comprised in the gen
D = *mk*N, where D is the deviation of a fixed line
trum of the *m*'th order, N the number of the elen
grating in a millimetre, and *k* a constant dependi
colour in which the line is situated.

To explain the mode of formation of these diffrac
let A*e* (*fig.* 653) be the surface of the grating, *a*
opaque spaces. Suppose the eye placed at C, and
CS of the line of light to be so great, that all the r
ing from it to the grating may be regarded as para
surface of the wave passing by the point A, as coincid
If the grating were removed, the slit *s* would be
direction CS, and no light at all would be seen i
direction, the elements of interference on the wave
ising one another by pairs. The presence of the
not impede the view of the slit, or alter its appare
and on each side of the slit there is a dark space, just as if the gratin
there. But at a certain distance A*d*, such that an opaque line of the gra

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covers the element of the wave which would counteract the action of the preceding element, light will be seen in the direction C*d*, the distance A*d* being greater in proportion as the eye is farther from the grating. If, for example, the angle AC*d* is of such a magnitude that $dC - oC = oC - cC = \frac{1}{2}\lambda$ of the violet, the vibrations communicated to the point C by the element *co*, will not be destroyed by *od*, and violet light will be seen in the direction C*o*, brighter in proportion as the edge of the dark space is nearer to *o*.

To calculate the deviation $dCA = d$, describe the arc *cr* having its centre at C; the triangle *dcr* gives $dr = \lambda = \overline{cd} \sin d$; and supposing *cd* to be contained N times in a millimetre, we have then $1 = N.\ \overline{cd}$, and the preceding equation gives $\sin d = N\lambda$, or taking the angle for the sine, $d = N\lambda$, which is in fact the general formula of the diffraction-spectra ($D = mk N$) applied to the case of the first spectrum. It shows that the deviation is independent of the difference between the opaque and the transparent spaces, and that the constant k is the length of an undulation corresponding to the colour under consideration. For the other colours, we find in like manner $d' = N\lambda'$, $d'' = N\lambda''$, &c., λ being greater λ, and λ'' greater than λ' &c. The colours will therefore appear one after the other, at angular distances sensibly proportional to λ, λ', λ'', &c.

Consider, in the next place, another element of the grating at such a distance from A that the difference $dC - cC = 2\lambda$, or in general to $m\lambda$, m being a whole number. The interval may then be divided into $2m$ elements of interference corresponding to differences of distance from C, equal to $\frac{1}{2}\lambda$, and these elements being of even number, the actions resulting from their several points would counteract one another two by two, if there were no opaque spaces. But if the opaque spaces cover an *uneven number of elements*, so that an uneven number also remains free, one of these latter will act unopposed, and there will be light in the corresponding direction. The triangle *cdr*, then gives $d = m\lambda N$, which is the general formula above given.

It remains to be seen why the light of any particular colour is wanting between the luminous band which corresponds to the difference of distance $m\lambda$ from C, and that which corresponds to $(m + 1)\lambda$. Now between the lines of the grating corresponding to these two bands, two zones may be found in which the differences of distance from the point C increases from $m\lambda$ to $m\lambda + \frac{1}{2}\lambda$, then from this latter to $m\lambda + 2 . \frac{1}{2}\lambda = (m + 1)\lambda$. The rays emanating from the corresponding points of these two zones differ in length of path by $\frac{1}{2}\lambda$, and destroy one another on reaching the point C. Dark bands will therefore occur in the direction of these zones. In white light, however, the colours, by overlapping one another, obliterate all these dark bands, excepting the first two on either side.

If the source of light is too near the grating to allow the rays to be regarded as parallel, the same mode of explanation is still applicable, only it becomes necessary to take account of the difference of path of the contiguous oblique rays at the moment when they reach the grating.

The formula $\sin d = m N\lambda$, shows that when $N\lambda$ is greater than 1, that is to say when $\frac{1}{N}$, or an *element* of the grating, is less than λ, $\sin d$ becomes greater than 1, which is impossible; in this case therefore no spectra can be formed, and in fact gratings which have their bars too close do not form any.

If the spectra are observed in any other medium, as when the slit and grating are placed at the opposite ends of a tube filled with water or other liquid, then, if l is the length of an undulation of violet light in that liquid, the deviation will be $d_1 = N\lambda$, which combined with the equation $d = N\lambda$, for the deviation of the same part of the spectrum in air, gives $d_1 : d = l : \lambda$, which is the ratio of the indices of refraction in the medium and in air.

Measurement of λ. The equation, $\sin d = N\lambda$, gives the means of measuring with great accuracy the wave-lengths corresponding to the several fixed lines of the spectrum, which cannot be done with the interference-fringes in Fresnel's experiment (p. 599), because the lines are not distinct. It is by this method that Babinet determined the values given in the table on p. 600.

Irregular Gratings.—Gratings whose bars are totally destitute of regular arrangement produce nothing but a whitish train of light at right angles to the bars: but if the irregularities are subject to a certain law and recur periodically, spectra are produced, whose deviation is expressed by the formula $\sin d = \frac{m\lambda}{L}$, in which L denotes the space comprising one complete set of bars. The successive spectra then differ greatly in brightness; some are very pale, and, occurring by the side of very bright ones, partly overlap them, but do not perceptibly alter their colours: hence lines may be distinguished in some of these spectra of the higher orders, which cannot be seen in the spectra of the correspond-

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ing orders formed by regular gratings, because they are obliterated by su
By looking at a candle with the eyes nearly closed, so that the eye-lashes
ing, a horizontal line of whitish light is generally seen, because the eye-la
the most part at unequal distances; frequently, however, very distinct spe
duced. Very fine spectra may be seen by looking at the sun or a bright fl
the plume of a crow's feather.

Gratings or Network with square or round bars or meshes.—Gratings
apertures may be formed of two sets of parallel bars crossing one another.
muslin or riband exhibits such a structure. Such gratings form a grea
small spectra, some disposed along the arms of a cross parallel to those of
others distributed obliquely in the four right angles. The appearance is v
and varies with the size of the meshes and the distance of the luminous po

Reflecting Gratings or Striated Surfaces.—When light is reflected fr
covered with striæ alternately bright and dull, the same spectra are produ
it is transmitted through a grating: for the reflected rays are in the sam
they had been transmitted through the striated surface from a point as f
the actual luminous point is before it; the spectra are not, however, quite
those produced by transmission. The iridescence of mother-of-pearl is
very fine striæ resulting from its foliated structure; a cast taken of it
mastic, or fusible metal, exhibits a similar iridescence. Fibrous gyps
colours due to the same cause. The feathers of certain birds likewise ow
liant colours to diffraction of the light reflected from the very fine filame
they are composed.

Half-polished metals sometimes exhibit iridescent colours, due to the p
produced by the hard powder used in polishing them; but as these stri
regular, the usual effect is merely a whitish line of light, at the points fro
rays are reflected to the eye. *Barton's buttons*, which are metallic but
very fine lines engraved on their surfaces by a peculiar machine, exhibit
diffraction spectra.

Reflection and Refraction.

When a wave of light reaches the surface of separation of two media
densities, its vibrations are not only propagated onwards into the second
likewise reflected back into the first, each particle of the ether at the surfa
tion then becoming a centre of disturbance from which fresh waves spre
directions. To find the directions of the reflected and transmitted wa
(*fig.* 655) be the separating surface of two media (air and water, for ex
$SabS'$ an incident beam of light of infinitely small section, so that the ray
it may be regarded as parallel, and the wave-surface, *bc*, perpendicular to th
as plane. Now the several points of this wave-surface, *cb*, do not all mee
MN at the same instant, but each point, as it reaches that surface, become
disturbance from which elementary waves are excited in both the media
MN. Moreover, the velocity of propagation of the waves in the two media
because the density of the ether in the one is greater than in the other (p
Suppose the lower medium to be the one in which the ether has the gre
and that the velocity of transmission of the light-waves in it is $\frac{3}{4}$ as gr
upper. Then, by the time the point *c* of the incident-wave has travelled on
will have spread out from *b*, in each medium, of a radius $bd = ac$ in the fir
$\frac{3}{4}\,ac$ in the second; also from any intermediate point *e* (*ea* being a porti
surface parallel to *bc*), a wave will spread out of radius $ed' = aa$ in the firs
$\frac{3}{4}\,aa$ in the second. Now each of these elementary waves produces no perce
by itself, a sensible disturbance of the ether or production of light takin
where a number of them act together, that is to say, in the first mediu
plane surface *ad*, and in the second along *af*; and straight lines *ar*, *br'*,
drawn at right angles to these surfaces from the several points between
give the direction of the reflected and transmitted rays.

In the first medium, the triangles *abc*, *abd* being equal in every respe
abd = the angle bac, that is to say, *the incident and reflected rays make
with the reflecting surface, and therefore also with the normal* **Pa**. The
these rays make with the normal are called the **angles of incidence**
tion respectively.

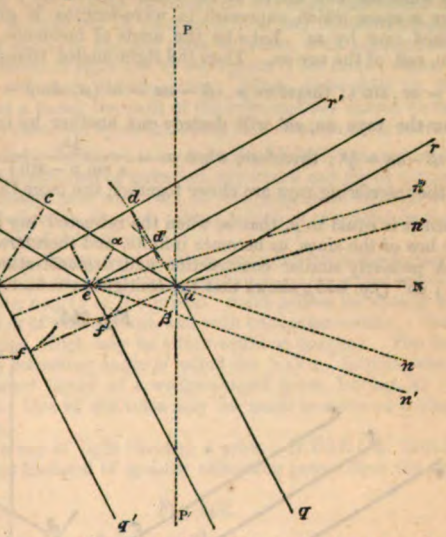
The symmetry of the figure with respect to the plane of incidence, *i*
passing through the incident ray and the normal, shows also that *the re
contained in the plane of incidence.*

The ray which passes on into the second medium is also contained in
incidence, but is bent or **refracted** out of its previous direction, and d
the same angle with the normal as the incident ray does. The angle
$Pas = i$ is equal to the angle cba, and the angle of refraction $P'aq = r$ is

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, abf give $ac = ab \sin i$; and $bf = ab \sin r$; therefore,

Fig. 655.



spaces *ac*, *bf* traversed by the ray in the same time, es v, v' of light in the two media: hence

$$\frac{\sin i}{\sin r} = \frac{v}{v'}.$$

gles of incidence and refraction are to one another in the velocities of light in the two media. This ratio, s of the waves $\lambda : \lambda'$ in the two media, is called the or relative, according as the ray passes from a vacuum m one ponderable medium to another. The absolute , usually denoted by the letter μ, is the reciprocal of dium referred to the velocity in a vacuum as unity; , μ' are the absolute indices of two contiguous media, n of a ray passing from the one to the other will be

$$\frac{\sin i}{\sin r} = \frac{\mu}{\mu'},$$

μ' are the indices of refraction of the ray in passing o two others, as water and glass.

t is to say, when the velocity of transmission, or the second medium than in the first, the ray is refracted ess than μ', it is refracted from the normal.

incidence may be such that the sine of the angle of eater than 1; under such circumstances, the ray does at all, but undergoes total reflection into the first. at which refraction ceases to take place, is given by the

$$\frac{\mu}{\mu'}.$$

refracted rays.—The preceding explanations show l refraction in the directions above determined, but d and refracted rays are confined to these directions; *ab* (*fig.* 655) is a centre of disturbance, from which s, it would seem as if rays should be reflected and d such is in fact the case; only, as Fresnel has shown, *and refracted beams rabr', qabq', destroy one another*

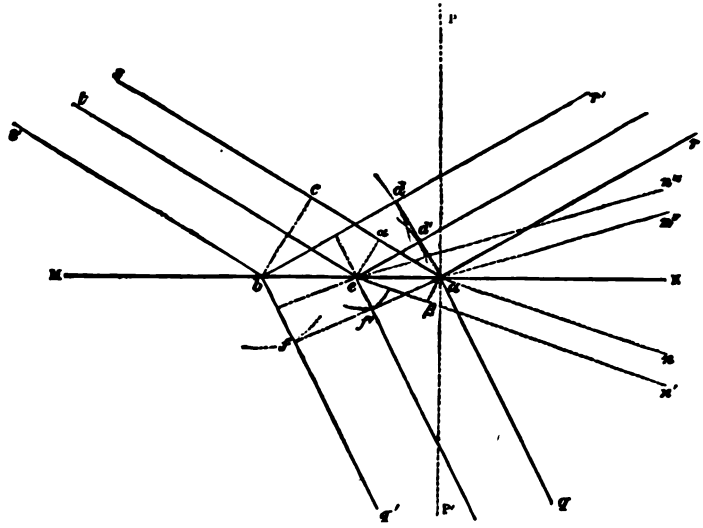
e two parallel refracted rays, very close together, but y the law of the sines. Draw *ea* and *aβ* perpendicular

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to sa and en'; then a vibration of the ray sa, in reaching the surface ab, will have travelled over a space greater by $a\alpha$ than the corresponding vibration of the ray te: but when the two arrive at the surface $a\beta$ of the refracted wave, te will have moved over a space which, expressed in wave-lengths, is greater, by $\mu . e\beta - a\alpha$, than that passed over by sa. Let i be the angle of incidence, αea, and ρ the angle of refraction, $ea\beta$, of the ray an. Then the right-angled triangles $e\beta a$, eaa give $e\beta = ae . \sin \rho$; $a\alpha = ae . \sin i$; therefore $\mu . e\beta - a\alpha = ae (\mu . \sin \rho - \sin i)$; and $ae = \frac{\mu . e\beta - a\alpha}{\mu . \sin \rho - \sin i}$. Now the rays an, en' will destroy one another by interference when the difference $\mu . e\beta - a\alpha = \frac{1}{2}\lambda$; therefore, when $ae = \frac{\frac{1}{2}\lambda}{\mu \sin \rho - \sin i}$. This shows that ae is smaller, or the interfering rays are closer together, the more the ratio $\frac{\sin i}{\sin \rho}$ differs from μ; but when it is equal to μ, that is, when the refracted ray is in the direction indicated by the law of the sines, ae becomes infinite, and therefore there is no interference.

A precisely similar construction and demonstration, applied to the reflected rays an'', en''' (*fig.* 655), shows that the contiguous reflected rays destroy each other in all

Fig. 655.



cases excepting when $\sin \rho = \sin i$, that is to say, when the reflected and incident rays make equal angles with the normal. If, however, the point a is very close to the left-hand edge of the mirror, the reflected ray en' will not exist, and an will not be destroyed. Hence if the mirror is very narrow, the rays reflected obliquely to the beam $rabr'$ are not completely destroyed, and the reflected beam becomes divergent. Fresnel verified this theoretical deduction by blackening the surface of a mirror, with the exception of a very narrow triangular space. The beam of light reflected from this space was broadest at the narrowest part of the reflecting surface, so that the image which it formed on a screen was a triangle with truncated summit, in a position the reverse of that of the reflecting triangle.

The reflected and refracted beams are always less bright than the incident beam. In fact, they would be together equal in intensity to the incident beam, were it not that part of the light is scattered in all directions, by reflection from minute irregularities on the surface of the medium; and secondly, that a portion of it, often very considerable, is apparently lost by absorption. This process doubtless consists in a communication of the vibratory motion of the ether to the particles of the ponderable body itself, the particles thus set in motion again acting as centres of vibration, and exciting fresh undulations in the surrounding ether, thereby rendering the body visible. The vibrations excited in the particles of a ponderable body by the movements of the ether likewise produce numerous changes in the state of the body itself, raising its temperature, and setting up certain chemical actions within it, which will be afterwards more fully considered. It is true that the ether transmits vibratory movements which render bodies hot, and others which determine chemical changes

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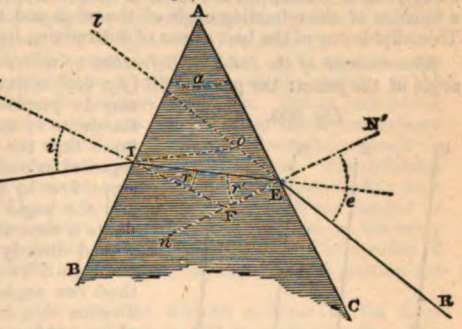
ng them visible; but it is probable that the lumin- alter the thermic and chemical conditions of a body, cules of the body, vibrations which result in thermic t again excite luminiferous waves in the ether. In light is lost in producing heat and chemical change. medium, such as glass or water, with polished sur- nount of light lost by absorption is but small; coloured reflect or absorb others. When light falls on the s a metal, the path of the refracted ray cannot be fol- y absorbed by an extremely thin stratum of the surface.

nd refraction having been established, the application a reflected or refracted ray under any given circum- netry, into which we do not propose to enter in this efraction through prisms, which is of special import- ces of refraction.

is a transparent medium, bounded by plane surfaces, edge in which these surfaces meet, or would meet, if ng angle of the prism. Solid prisms for optical use or of rock-crystal, and with triangular section. Such les, which may be either equal or unequal. The face refracting angle is called the base. Liquid prisms rent liquid in a wedge-shaped glass, having its in- . One of the sides may be made to move on a hinge

a ray of light through a prism. If BAC (*fig.* 656) be nt material of greater refracting power than the sur-

Fig. 656.



gly an eye placed at R will see an object S in the moved upwards towards the summit of the prism. ween the incident and emergent rays is called the dently equal to the sum of the angles IE*o*, E*I*o; that e triangle IEF shows that $r + r' = \text{IF}n$, the angle s, and therefore to the refracting angle of the prism, a. by the formula:

$$D = i + e - a.$$

it increases with the refracting angle of the prism δ, then since r is constant, and $r + r' = a$, r' must e by $\mu\delta$, μ being greater than 1; that is to say, e in- ently D increases.

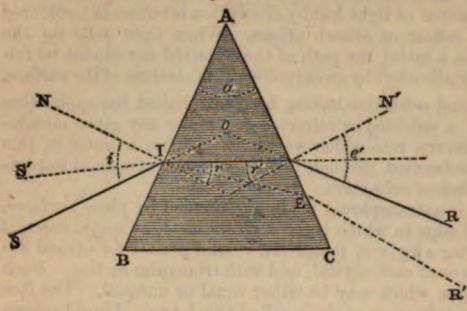
constant, the deviation varies with the angle of n value when the incident and emergent rays make urfaces. To show, in the first place, that this latter t an incident ray coinciding with the normal NI (*fig.* he position SI; the angle r, which is at first equal to , and therefore r' must diminish, since $r + r' = a$; an 180°, and r may increase to 90°, the incident ray tion in which $r = r'$, and therefore $i = e$.

e the rays which make equal angles with the normals; position S'I closer to the normal; r will then diminish.

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and therefore r' must increase by the same quantity; e will therefore also i
become greater than i. But $\frac{\sin i}{\sin r} = \frac{\sin e}{\sin r'}$; and since sin e and sin r' are
sin i and sin r, the difference between sin e and sin r' must be greate
between sin i and s
tiori, therefore, the
r' must differ more
The angle e has t
creased more than
nished, and conse
deviation, $D = i +$
also have increased
lar way, it may be s
the incident ray ent
the increase of i wi
than the diminution
deviation is therefo
by shifting the ray S
from its position, th
the deviation is a mi
the incident and em

Fig. 657.



are equally inclined to the surfaces of the prism, or to the normals.

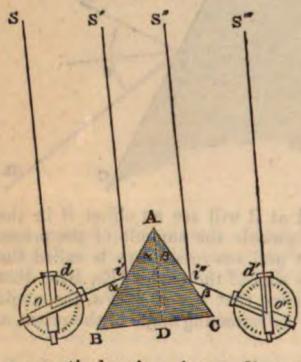
In this case, the expression for the deviation becomes $D = 2i - a$, whic
$\frac{a + D}{2}$; also, since r and r' are equal, we have $r = \frac{a}{2}$: hence also:

$$\mu = \frac{\sin i}{\sin r} = \frac{\sin \frac{1}{2}(a + D)}{\sin \frac{1}{2} a};$$

an expression which gives the index of refraction of the medium forming t
a function of the refracting angle of the prism and the angle of minimu
This affords one of the best means of determining indices of refraction.

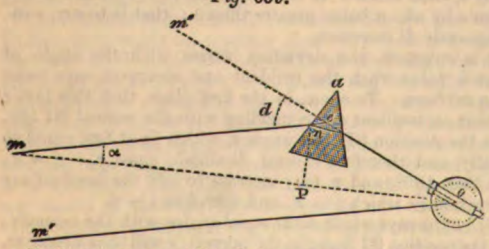
Measurement of the Index of Refraction of Solids and Liquids.—1. To
angle of the prism: the prism ABC (*fig.* 658) is fixed in such a manner t
may be perpendicular to the divided
theodolite o; and a mark S, placed at
tance that the rays proceeding from
regarded as parallel, is viewed throu
scope, first by reflection from AB, th
and the angle $S\,o\,i = d$ is measured.
dolite is then moved to o', and the sa
viewed directly and by reflection fro
the angle $S'''\,o\,i = d'$ is measured. Hal
these two angles is the measure of t
To show this, draw AD parallel to t
of the incident rays, and dividing the
two parts, α and β. Then $\alpha = S'iA$
therefore $2\alpha = 180° - S'io$. But Soi
$- S'io$; therefore $d = 2\alpha$. In like ma
be shown that $d' = 2\beta$; consequentl
$A = \frac{1}{2}(d + d')$.

Fig. 658.



2. To measure the minimum dev
prism is fixed on a support capable
on a vertical axis. A very distant mark m (*fig.* 659) is viewed with the t
first directly in the direction om, then through the prism in the directio

Fig. 659.



the prism is turne
the angle mom'' be
two directions is
its smallest possi
tude. The angle
mined is the ang
mum deviation, pr
mark is so distan
rays proceeding fr
be regarded as p
distant lightning
forms a very gooc
the purpose in the
a slit in the shutter of a dark room, provided the room be large, may als

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al light, with a lamp surrounded by a jacket of tin

ldom far enough off to allow the divergence of the
e angle of divergence, and o the angle mom''. The

$$-m''cm) = a + o + 180° - (2i - a).$$

d therefore

$$= \frac{\sin \frac{1}{2}(a + o + \alpha)}{\sin \frac{1}{2}a}.$$

transporting the theodolite to m. But as α is very
fficient to measure the length of the perpendicular
ning a cord from o to m; then $\tan \alpha = \frac{nP}{mP}$.

btaining parallel rays is by the use of the colli-
f a telescope-tube blackened inside, and having two
ntal, fixed within it, and crossing in its axis. When
indow, the wires, being illuminated by a beam of
may be regarded as an object placed at an infinite
d at one end of the tube, and the cross-wires in its
be used in the same manner for observations with
end of the tube is directed towards a lamp, the rays
ction of the wires will issue parallel after passing
e be brought to a focus by another telescope just
al object.

refraction, it is necessary to specify the colour of
refers. Solar light, and lamp, candle, or gas light
nd separable by refraction into coloured rays of
y, any line of light viewed through a prism appears
of colour parallel to its edges. It is usual to make
s, which are situated towards the middle of the
ossess the greatest brightness. But as each colour
pectrum, and the boundaries of the several colours
no means certain that two observations made on
tly the same part of the spectrum. The difficulty
ly removed by the observation of certain fine dark
the solar spectrum (p. 620), which are parallel to
ent colours, and are always disposed in the same
nay be the nature of the prism. The spectra of
xhibit bright bands, likewise of fixed position for

may be obtained without recourse to the fixed
re of the collimator with a sewing needle. The
es of the needle overlap one another towards the
of separation between two very distinct colours, a
(H. Deville.)

dices by Interference.—The displacement of the
600) furnishes a very delicate method of determining
the transparent substance being placed before one of
recept part of the pencil of rays reflected from it, the
e central fringe is displaced is observed. Let R be
film, m and m' the number of wave-lengths, λ and λ',
he air and the transparent film: then

$$\text{whence } \frac{m'}{m} = \frac{\lambda'}{\lambda} = \frac{v'}{v} = \mu.$$

laced through R ranks, we have also $m' = m + R$,
film displacing the central band one rank further.

$$= \frac{m + R}{m} = \frac{e + R\lambda}{e},$$

refraction in terms of the thickness of the film and

able to gases and vapours (p. 618).

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Determination of the Index of Refraction of Liquids.—*deviation.* The liquid is inclosed in a wedge-shaped vessel, o a transverse section. The sides are formed of thin plate-g the accuracy of the observations that the two fa

Fig. 660.

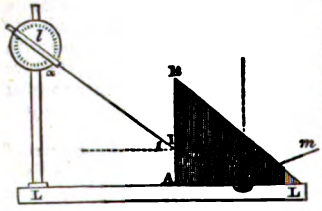


should be parallel. As, however, this condition filled, it is necessary to measure the deviatio when empty, previous to making the observat examined. The first deviation is then to be d the second, according as it is in the same or in

As liquids are very expansible by heat, thei be sensibly affected, even by variations of temperature not e rounding atmosphere. It is necessary, therefore, to make the temperature, to agitate the liquid briskly before making the using the direct rays of the sun, which might heat it unequal

2. *By total reflection.*—This method is especially applicabl of liquid; also to imperfectly transparent liquids and past crystalline lens of the eye. A small drop of the liquid is att of a right-angled prism BAL (*fig.* 660), resting on a horizo hole o is made to rece must be formed of a su tive index, greater than drop of liquid is viewe means of a small tel centre of a graduated down a vertical rule L telescope is at first fix objects below the drop on gradually lowering angle Ion continually i rays coming from the at m are totally reflec observed. The angle

Fig. 661.

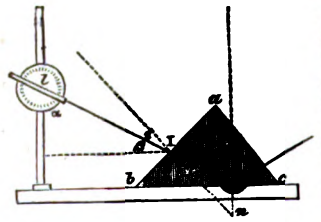


is then fixed, and the angle α is the limiting angle θ, and $\sin\theta = \frac{\mu'}{\mu}$, μ being the refractive i that of the liquid. Now the angle $\theta = 90° - r$; therefore $\mu \cos\theta$; hence $\cos\theta = \frac{\cos\alpha}{\mu}$, and $\sin\theta = \frac{1}{\mu}\sqrt{\mu^2 - \cos^2\alpha} = \frac{\mu'}{\mu}$;

$$\mu' = \sqrt{\mu^2 - \cos^2\alpha}.$$

Wollaston devised a modification of this method by which th determined without cal

Fig. 662.



ments of Chemistry, 3r *Traité de Physique*, 2me trouble of calculation mula is not, however the method. A mo arises from the difficu exactly rectangular. T Malus uses an acute-an angle b of which is being made as above before, $\beta = 90° - \alpha$ a normal In be produced in n; then the angle n is equal to the angle b of the pris gives $\theta = r + b$; whence $\sin\theta = \frac{\mu'}{\mu} = \sin(r + b) = \sin r$ $\mu \sin r = \sin i$; and the triangle $In'n$ gives $n'In = i$ $i = 90° - (b + \beta)$: therefore

$$\sin r = \frac{1}{\mu}\cos(b + \beta);$$

and

$$\cos r = \frac{1}{\mu}\sqrt{\mu^2 - \cos^2(b + \beta)}.$$

This gives; $\mu' = \mu \sin\theta = \cos(b + \beta)\cos b + \sin b\sqrt{\mu^2 -$

This method may also be applied to solids. Soft bodi organic bodies may be at once attached to the lower surf

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bodies may be attached by means of a liquid of *greater refracting power* than the prism: the total reflection will then take place just as if the solid were immediately attached.

The same method also gives the index of refraction of the prism itself, the observation being made without applying any liquid to the lower face. In this case, since the medium below the prism is air, we have $\mu' = 1$, and the formula gives

$$\mu = \frac{1}{\sin b}\sqrt{1 + \cos^2(b + \beta) - 2\cos b \cos(b + \beta)}.$$

The following tables contain the indices of refraction of several solids and liquids, determined by the preceding methods. They all relate to the yellow rays of the spectrum, excepting those of Wollaston, which relate to the extreme red:

Indices of Refraction of Solids.

Name of substance.	Index of refraction.	Observer.	Name of substance.	Index of refraction.	Observer.
Chromate of lead	2·50 to 2·97	Brewster.	Sugar	1·535	Wollaston.
Diamond	2·47 to 2·75	Br.; Rochon.	Phosphoric acid	1·534	Brewster.
Phosphorus	2·224	Brewster.	Sulphate of copper	1·531 to 1·552	„
Glass of antimony	2·216	„	Canada balsam	1·532	Young.
Sulphur (native)	2·115	„	Citric acid	1·527	Brewster.
Zircon	1·95	Wollaston.	Crown glass	1·525 to 1·534	„
Borate of lead	1·866	Herschel.	Nitre	1·514	„
Carbonate of lead	1·81 to 2·08	Brewster.	Plate-glass	1·514 to 1·542	„
Ruby	1·779	„	Spermaceti	1·503	Young.
Felspar	1·764	„	Crown glass	1·500	Wollaston.
Tourmalin	1·668	„	Sulphate of potassium	1·500	Brewster.
Topaz, colourless	1·610	Biot.	Ferrous sulphate	1·494	„
Beryl	1·598	Brewster.	Tallow; wax	1·492	Young.
Tortoise-shell	1·591	„	Sulphate of magnesium	1·488	Brewster.
Emerald	1·585	„	Iceland spar	1·654	Malus.
Flint glass	1·57 to 1·58	Br.; W.	Obsidian	1·488	Brewster.
Rock-crystal	1·547	Wollaston.	Gum	1·476	Newton.
Rock-salt	1·545	Newton.	Borax	1·475	Brewster.
Apophyllite	1·543	Brewster.	Alum	1·457	Wollaston.
Colophony	1·543	Wollaston.	Fluor spar	1·436	Brewster.
			Ice	1·310	Wollaston.
			Tabasheer	1·1115	Brewster.

Indices of Refraction of Liquids.

Name of liquid.	Index of refraction.	Observer.	Name of liquid.	Index of refraction.	Observer.
Sulphide of carbon	1·678	Brewster.	Solution of potash (specific gravity 1·410)	1·405	Fraunhofer.
Oil of cassia	1·031	Young.	Hydrochloric acid (concentrated)	1·410	Biot.
Bitter almond oil	1·603	Brewster.	Sea-salt (saturated)	1·575	„
Nut-oil	1·500	„	Alcohol (rectified)	1·372	Herschel.
Linseed-oil	1·485	Wollaston.	Ether	1·358	Wollaston.
Oil of naphtha	1·475	Young.	Alum; saturated	1·356	Herschel.
Rape-oil	1·475	Brewster; Young.	Human blood	1·354	Young.
Olive-oil	1·470	Brewster.	White of egg	1·351	Euler, jun.
Oil of turpentine	1·470	Wollaston.	Vinegar, distilled	1·372	Herschel.
Oil of almonds	1·469	„	Saliva	1·339	Young.
Oil of lavender	1·457	Brewster.	Water	1·336	Wollaston; Brewster.
Sulphuric acid (specific gravity 1·7)	1·429	Newton.			
Nitric acid (specific gravity 1·48)	1·410	Young; Wollaston.			

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The indices of refraction assigned to the same substance by different ob exhibit considerable diversities, arising partly from imperfection of meth cially from want of chemical or physical identity in the substances exami

A comparison of the indices of refraction of different substances lead general conclusions. One of the most remarkable is that inflammable s strongly refractive: *e. g.*, sulphur and phosphorus among solids; oils and among liquids; it was the observation of this fact that led Newton to i diamond would be found to contain an inflammable principle.

Generally speaking, the refracting power of *any one substance* increases sity; though it is by no means true that the refracting powers of different s proportional to, or even follow in the same order as their densities. Jami method presently to be noticed, that the refracting power of water is incr pression. On the other hand, the refracting power of liquids is diminish are expanded by heat. Brewster found that the index of refraction of c which, at ordinary temperatures, is equal to 1·358, is reduced to 1·057 whe of the ether is tripled by heat. Numerous experiments on this subject ha by Dale and Gladstone (Phil. Trans. 1858; Ann. Ch. Phys. [3] lv operated on twelve different liquids between the temperatures of 3° and method of minimum deviation. The prism was placed horizontally and spirit-lamp or cooled by a freezing mixture. The temperature was in thermometer with which the liquid was stirred. The following table conta of the results (see also page 625); they relate to the line D of the so excepting those with phosphorus, which relate to the line C:

Tempera-ture.	Sulphide of carbon.	Water.	Ether.	Alcohol, absolute.	Methyl-alcohol.	Phosphor liquid.
0°	1·6442	1·3330				
10	1·6346	1·3327	1·3592	1·3658	1·3379	
20	1·6261	1·3320	1·3545	1·3615		
30	1·6182	1·3309	1·3495	1·3578	. .	2·0741
40	1·6103	1·3297	. .	1·3536	1·3297	2·0677
50	. .	1·3280	. .	1·3491	. .	2·0603
60	. .	1·3259	. .	1·3437	. .	2·0515

The refractive index of *water* diminishes continuously between − 1·3° the direction of the variation not changing in the passage through the point density. (Arago. Jamin. Dale and Gladstone.)

In the passage of a body from the solid to the liquid state, the refr sometimes diminishes, as in the case of *phosphoric acid*, *wax*, and *tallow*. it increases, as with *water* and *borax*; sometimes again it does not change as is the case with *sugar*.

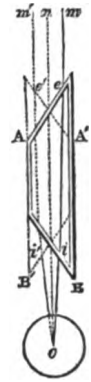
H. Deville (Ann. Ch. Phys. [3] v. 129) has measured the index of *alcohol*, *wood-spirit*, and *acetic acid*, mixed with water in different proport substances exhibit the greatest degree of contraction, or of density, when uni water (*e. g.*, $2C^2H^6O.3H^2O$). It is also with this proportion of water tha and acetic acid exhibit the highest degree of refractive power, whereas this is the case when it contains ½ at. water ($2C^2H^6O.H^2O$). At 16° the dex of absolute alcohol is 1·3663; that of $2C^2H^6O.H^2O$ is 1·3662; that methylic alcohol, CH^4O, is 1·3358; of $2CH^4O.3H^2O$, 1·3462; that acetic acid, $C^4H^6O^3$, is 1·3753; and of $2C^4H^6O^3.3H^2O$, 1·3781.

Index of Refraction of Gases. Refractive Power. Biot and Arago the refractive index of atmospheric air, by the method of minimum devia hollow glass prism, called a *Borda's prism*, consisting of a glass tube (*fig.* centimetres in diameter, and having its ends *a*, *b* cut in a slanting directio with very thin plates of parallel glass. The prism was mounted, with its ref vertical, on a brass tube connected with a stop-cock and screwed on to th air-pump. The pressure of the air in the tube was measured by connect siphon-gauge. The tube having been exhausted, filled with dry air seven again exhausted, observations were made with it similar to those describ with this exception however, that as the refracting power of the exhauste less than that of the surrounding air, the *maximum*, instead of the *minim* was observed. The deviations being extremely small, the thickness of th vented the mark from being viewed directly. To obviate this difficulty, a had been viewed through the prism represented in section at AB, and t deviation of the ray *m e i o* observed, the prism was moved half round into

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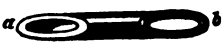
AB, and the same mark again observed. The image m was thereby thrown to the opposite side of the ray no proceeding directly from the object, so that the angle ios' was equal to twice the angle noi. This method gave for the index of refraction of air at 0° C. and 0·76 met. barometric pressure, referred to a vacuum as the unit, the number 1·00294.

Fig. 663.



In like manner, the indices of refraction of other gases were determined, referred to that of air as unity.

Now on measuring in this manner the refraction produced by air or other gases at different densities, it was found that, at pressures not exceeding that of the atmosphere, the quantity μ^2-1, which is called the **refractive power**, is proportional to the density of the gas—in other words, that $\frac{\mu^2-1}{d}$, which may be called the **specific refractive power**, is a constant quantity. The law was not verified for pressures greater than that of the atmosphere, on account of the difficulty of retaining condensed gases within the hollow prism.



Dulong determined the refractive powers of a considerable number of gases and vapours by the following method, founded on the proportionality of the refractive power to the density. A distant mark is observed by a telescope through a Borda's prism filled with dry air, at a pressure h. The prism and telescope are then fixed, and the prism is filled with another gas, the pressure of which is varied till the image of the mark again coincides with the wire of the telescope. The refractive index of the gas under the pressure h', is then equal to that of the air under the pressure h. If then μ' and μ are the indices of refraction of the gas and of air at the same pressure h, and at the same temperature, we have, since the index of the gas under the pressure h' is equal to μ,

$$\mu'^2-1 : \mu^2-1 = h : h',$$

whence μ' is easily found.

Refractive power of Gases.

Name of gas.	Refractive power.			Index of refraction.	Density.
	Compared with that of air.	Excess over calculation.	Absolute. μ^2-1.		
Air	1·000	. .	0·000589	1·000294	1·000
Oxygen	0·924	. .	0·000544	1·000272	1·106
Hydrogen	0·470	. .	0·000277	1·000138	0·069
Nitrogen	1·020	. .	0·000601	1·000300	0·971
Chlorine	2·623	. .	0·001545	1·000772	2·470
Nitrous oxide	1·710	+ 0·228	0·001007	1·000503	1·520
Nitric oxide	1·030	+ 0·058	0·000606	1·000303	1·039
Hydrochloric acid	1·527	+ 0·020	0·000899	1·000449	1·247
Carbonic oxide	1·157	. .	0·000681	1·000340	1·957
Carbonic anhydride	1·526	− 0·093	0·000899	1·000449	1·524
Cyanogen	2·832	. .	0·001668	1·000834	1·806
Ethylene	2·302	. .	0·001356	1·000678	0·978
Marsh gas	1·504	. .	0·000886	1·000443	0·555
Chloride of ethyl	3·720	− 0·099	0·002191	1·001095	2·234
Hydrocyanic acid	1·531	− 0·130	0·000903	1·000451	0·944
Ammonia	1·309	+ 0·093	0·000771	1·000385	0·596
Phosgene	3·936	+ 0·152	0·002318	1·001159	3·442
Sulphydric acid	2·187	. .	0·001288	1·000644	1·191
Sulphurous anhydride	2·260	. .	0·001331	1·000665	2·234
Ether	5·197	. .	0·003061	1·001153	2·580
Sulphide of carbon	5·110	. .	0·003010	1·001150	2·644
Phosphoretted hydrogen	2·682	. .	0·001579	1·000789	1·214

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By this method Dulong has shown: 1. That the refractive power of a mixture of gases is equal to the mean of those of the constituent gases calculated for the pressure to which each gas is actually subjected in the mixture. 2. That the refractive power of a compound gas is not equal to the mean of those of the component gases, but is sometimes greater and sometimes less. The third column of the following table exhibits the differences *between* the actual refractive powers of certain compound gases, and those which would be obtained by adding together the refractive powers of the several components, and dividing by the volume of the compound gas. The refractive power of atmospheric air is found to be exactly the mean of those of its two constituent gases, a fact which shows, together with others, that the air is a mixture, and not a compound of oxygen and nitrogen.

The numbers in this table show that there is no simple relation between the refractive powers of different gases and their densities; hydrochloric acid gas, for example, has a lower density, but much higher refractive power than sulphurous anhydride, and ether-vapour has about the same density as chlorine, but double the refractive power.

The interferential method, the principle of which has been already described, is very well adapted to the measurement of the refractive indices of gases, and gives results more exact than those of the preceding methods. Arago and Fresnel applied it to the comparison of the refractive indices of moist and dry air. The interfering rays were made to pass through two copper tubes, each a metre in length, and closed at the ends with glass plates having exactly parallel faces, the one being filled with moist and the other with dry air. The fringes were then found to be displaced to the amount of one band and a quarter on the side of the dry tube, showing that moist air is rather less refractive than dry air. *Precipitated vapour* was found to produce a very slight increase in the refracting power of the air.

An improved apparatus for experiments of this kind has been constructed by Jamin, but we must refer for the description of it to his memoir (Ann. Ch. Phys. [3], xlix. 382), or Daguin's *Traité de Physique*, iv. 402. By means of this apparatus, Jamin has shown that vapour of water, at the temperature of 0° and at 0·76 met. barometric pressure, supposing it could exist under those circumstances, would have an absolute index of refraction equal to 1·00261, which is less than that of air at the same temperature and pressure. The refractive power of aqueous vapour calculated by the formula $\mu^2 - 1$ is therefore = 0·000521.

By adding to the refractive index of dry air that of aqueous vapour in the saturated state, under the pressure which it possesses at 20°, Jamin finds that the difference between the refractive indices of dry air and air saturated with aqueous vapour is only 0·000000726, a quantity which is too small to produce any sensible effects with Borda's prism, and may be safely neglected in the calculation of atmospheric refraction for astronomical purposes.

Refractive power of vapours produced at high temperatures. Leroux (Ann. Ch. Phys. [3], lxi. 385) has measured the refractive indices of a few of these vapours by the method of least deviation, using a hollow prism of iron having part of its opposite faces replaced by flat glass plates, and provided with proper appliances for heating, and for keeping the pressure of the vapour equal to that of the atmosphere. The indices and refractive powers of the vapours examined are as follows:

Substance.	Absolute index of refraction.	Refractive power $\mu^2 - 1$.
Sulphur . . .	1·001629	0·003258
Phosphorus . .	1·001364	0·002728
Arsenic . . .	1·091114	0·002228
Mercury . . .	1·000556	0·001112

Dispersion.

When a narrow beam of the sun's rays is passed through a glass prism (*fig.* 664) and received upon a screen, an elongated image or spectrum is formed, exhibiting a series of brilliant colours in the following order:

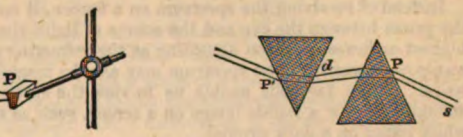
Red. Orange. Yellow. Green. Blue. Indigo. Violet.

the red occupying the lowest or the highest place, according as the refracting angle of the prism is turned downwards or upwards. The different coloured rays are therefore refracted by the prism in different degrees, the red exhibiting the least, and the violet the greatest deviation. Moreover, if a small hole be made in any part of the screen so as to allow a narrow beam of the rays of any one colour to pass, and this beam be transmitted through another prism, it will not again be elongated and split up into

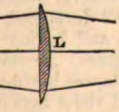
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on a second screen an image of the same shape as the
as the beam before passing through the second prism.
red exhibits the least, the violet the greatest devia-

Fig. 665



ind that Newton made the grand discovery, that *Solar*
n into a number of rays of different colours, and that
distinct degree of refrangibility, the red rays being the
le, and the intermediate colours increasing regularly in
violet.
fact that the reunion of the colours of the spectrum
be shown by receiving the beam of light *s*, refracted
econd prism P' of the same substance and having the
are thus brought back to parallelism and form a beam
pparatus for exhibiting this recomposition of white
n divided in halves by a diagonal glass partition On
isions and passing a beam of sunlight through it, a
on pouring water into the second division, the rays
nd the emergent beam is white.
g the recomposition is to colour a circular piece of
ints of the spectrum, and give it a rapid rotatory
ess than the tenth of a second (the time during which
ina) the whole surface appears of a uniform greyish-
perfect whiteness arising from the impossibility of
he spectrum by pigments.
n of the colours of the spectrum, the prism should have
aperture should be as narrow as possible: for a wide
number of narrow ones side by side, each of which
olours of the several spectra thus formed overlapping
und tints; indeed, if the aperture exceeds a certain
ill receive rays of all colours and will appear white.
f light must not be divergent, and the apparent dia-
which the light proceeds must be as small as possible·
ough a very small aperture is more divergent as the
of light is larger; the sun's rays passing through such
a vertical angle of 30 minutes. Newton obtained a
very bright and pure spectrum by passing a broad and thick rectangular beam of light through a convex lens L (*fig.* 666) of long focus, placed very near the prism P, and receiving the light on a white screen placed in the focus of the lens. Each colour is then brought to a focus on the screen, forming a bright narrow spot, the whole producing a very pure spectrum *rv*. An improvement on



drical lens parallel to the edges of the prism, whereby
ed into a thin focal band well separated from the rest.
rovement by interposing, between the lens and prism,
ich would pass too near the edge of the lens, and dimi-
ed images. The spectrum is more elongated in pro·
er to the prism, which is then farther from the screen,
minate distance from the lens.

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To obtain a beam of perfectly homogeneous light, a coloured beam passing through a small hole in the part of the screen on which the spectrum produced as above is received, is transmitted through a second prism; and if the deflected image thus formed is at all elongated, showing that the original coloured beam was not quite homogeneous, the light of a portion of it must be passed through an aperture in a second screen placed to receive it. A ray thus separated will be found to be perfectly homogeneous in colour, and of uniform refrangibility.

Instead of receiving the spectrum on a screen, it may be viewed directly by holding the prism between the eye and the source of light, the red rays then appearing in the highest or lowest position according as the refracting angle of the prism is held downwards or upwards. The spectrum may also be magnified by viewing it through a telescope. These methods enable us to view the spectra of sources of light not bright enough to throw a visible image on a screen, such as the light reflected from a strip of white paper on a dark ground.

The spectra of the moon and planets, and of white terrestial objects illuminated by solar light, are similar to that obtained with the direct rays of the sun. The spectra of the fixed stars exhibit the same colours and nearly in the same proportions. Those of ordinary flames (hydrocarbon flames) likewise exhibit the same colours, but with a larger proportion of yellow. That of an alcohol flame consists mainly of yellow light, and if a little common salt be mixed with the alcohol, the flame gives a perfectly monochromatic yellow light. The flame of a Bunsen's burner in which a salt of lithium is ignited, gives a spectrum consisting almost wholly of red light; and when a salt of thallium is ignited in it, the spectrum consists wholly of green light.

Fixed Lines in the Solar Spectrum.

Newton, by passing a beam of light proceeding from a small circular aperture through a prism, obtained a spectrum which appeared perfectly continuous, whence he concluded that white light contained rays of all degrees of refrangibility, regularly increasing from the red to the violet. But Wollaston in 1802, by looking through a good flint glass prism at a very narrow rectangular aperture illuminated by sun-light, perceived that the spectrum was intersected by several very fine dark lines parallel to the edges of the prism, or to the boundary lines of the several colours; and fifteen years afterwards, Fraunhofer of Munich, without being acquainted with Wollaston's observations, made the same discovery by viewing a spectrum formed in the manner just described through a telescope. The lines were very fine, all dark, and some perfectly black, and Fraunhofer was able to count between 500 and 600 of them, their number increasing with the magnifying power of the telescope. These lines are distributed irregularly throughout the whole length of the spectrum, and do not, for the most part, occur at the limits of the principal colours. Eight of them, easily distinguished by their position and intensity, are denoted by the first eight letters of the alphabet, beginning from the red of the spectrum: they are shown in *fig.* 667. Some of them, when examined by a good magnifying power in a well-developed spectrum, are resolved into a number of fine lines very close together. There are two more groups of lines which are particularly conspicuous, one denoted by *a*, consisting of eight fine lines in the red between A and B, and another *b* in the green near E, consisting of three fine lines, the two stronger of which are separated by a bright space.

These dark lines show that the solar spectrum is not continuous; in other words, that there do not exist rays of all degrees of refrangibility between the red and the violet.

The aspect, order, and relative distances of the lines in the solar spectrum remain the same, for a prism of given substance, whatever may be the magnitude of its refracting angle; but if the substance of the prism be changed, the relative distances of the fixed lines and the relative widths of the several coloured spaces are likewise altered.

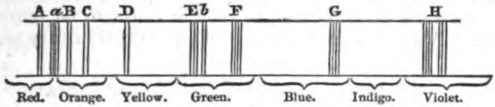
To obtain the lines of the spectrum well developed, it is necessary to use a prism of very uniform substance, free from striæ, and having a refracting angle large enough to yield a very pure and extended spectrum. Prisms for the purpose are generally made of flint glass or rock-crystal, substances having a high dispersive power, that is to say, the power of refracting the red and violet rays in very different degrees (p. 623). A hollow prism filled with sulphide of carbon is also well adapted for the purpose, as it is sure to be uniform, if preserved from variations of temperature, and its dispersive power is very great. To form the spectrum, the sun's rays, or the diffused light of the sky, entering a darkened room through a narrow slit, or condensed by a cylindrical lens, are made to pass through the prism, and the dispersed beam of light is viewed through an achromatic telescope. The lines and intermediate spaces are thereby magnified, the number seen being greater in proportion to the magnifying power of the telescope. The most favourable position for the prism is that of minimum deviation.

Lines also exist beyond A in the red, and beyond the violet in a space occupied by very faint lavender-coloured rays. The first were observed by Brewster in a space

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equal to AB (*fig.* 667), the second by Sir John Herschel. To render these lines visible, several precautions are required; amongst others it is necessary to intercept all the rays between the red and violet, and line the tube of the telescope with black velvet. By

Fig. 667.



adopting these and other precautions, and using a prism of oil of cassia, which possesses a high dispersive power, Brewster was able to distinguish altogether about 1000 lines in the spectrum, a map of which, together with a delineation of the two extremities of the solar spectrum, as observed by Gladstone when the sun was at about his greatest altitude, is given with a paper "On the Lines of the Solar Spectrum" by Brewster and Gladstone, published in the Philosophical Transactions for 1860, p. 149.

A still greater development of the spectrum, and an increased number of lines, are obtained by passing the rays through a series of prisms. In this manner Kirchoff has observed about 2000 lines, and has been enabled to lay down a very elaborate map of the solar spectrum, which is published in his work, translated by Roscoe, under the title—*Researches on the Solar Spectrum, and on the Spectra of the Chemical Elements.*

Gassiot has constructed a train of nine flint glass prisms with angles of 45°, and another of eleven sulphide-of-carbon prisms with angles of 45°, with which further observations have been made. (Proc. Roy. Soc. xii. 536; xiii. 183.)

Solar light reflected from a white surface, also that of the clouds, and that of the moon and planets, give spectra exhibiting the same principal lines, and disposed in the same order, as in the spectrum formed by the direct rays of the sun. In the spectra of Mars, Jupiter, and Venus, the lines D, E, F may be very clearly distinguished. But the fixed stars give spectra containing different lines. That of *Sirius* contains two dark lines in the blue, and one very strong line in the green, but none in the yellow or orange; that of *Pollux* contains several faint lines, the line D occupying apparently the same place as in the solar spectrum. See further a paper by Huggins and Miller. (Proc. Roy. Soc. xiii. 64.)

Effect of coloured Gases on the appearance of the Lines. When a ray of light passes through a coloured gas before falling on the prism, dark lines make their appearance due to the absorption of certain rays by the gas. When the light of a lamp, which of itself gives a spectrum containing only bright lines (p. 622), is passed through the red vapour of pernitric oxide, the violet and blue portions of the spectrum are covered with black lines or rather bands, which become broader as the density of the gas is increased, and ultimately join, so as completely to obliterate the violet rays; at the same time dark lines make their appearance in the yellow, and ultimately extend into the red (Brewster, Phil. Mag. [3], viii. 384). Iodine- and bromine-vapours produce dark lines different from those formed by pernitric oxide, appearing first in the green and yellow, then in the orange, and at the commencement of the red, some being quite black while others formed dark bands. The mere existence of colour in a vapour does not, however, necessitate the existence of bands in its spectrum. The red vapours of chloride of tungsten, for example, give no lines whatever. Neither can the position of the lines be inferred from the colour of the gas; with green perchloride of manganese, they are most abundant in the green, while with the red vapours of pernitric oxide, they increase in depth and number as they approach the violet. The vapours of simple bodies as well as of compounds may produce lines, and two simple bodies which singly do not produce them, may produce them abundantly in their compounds; *e.g.*, neither oxygen, nitrogen, nor chlorine, when uncombined, produces lines, but some of the oxides, both of nitrogen and chlorine, exhibit the phenomena in the most striking manner. There are, however, oxides both of nitrogen and chlorine, some of them coloured, which do not occasion the appearance of lines. Lines may also be produced by simple substances, which disappear in their compounds; thus iodine produces lines which do not appear in the spectrum of hydriodic acid. Sometimes the same lines are produced by different degrees of oxidation of the same substance, a remarkable instance of which is afforded by the oxides of chlorine. (W. A. Miller, *Elements of Chemistry*, 3rd ed. i. 164.)

When solar light is passed through a coloured vapour, the density of which is gradually increased, absorption-bands make their appearance, faint at first and easily distinguished, but gradually becoming blacker, and ultimately obliterating the ordinary lines. The two systems of lines are in fact distinct in the spectra of all coloured vapours, excepting that of pernitric oxide, in which they coincide. (Brewster.)

As the atmosphere possseses a slight colour, it is possible that some at least of the

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ordinary lines of the solar spectrum may be due to the absorption o during their passage through the earth's atmosphere; and in fact the numerous, and some of them, especially those in the red, are remarkabl the sun is near the horizon, and its rays have consequently to travel thr thickness of atmospheric air, than when he is at a greater altitude; number of the lines are probably due to another cause, to be consid (Brewster and Gladstone, Phil. Trans. 1860, p. 149; Gladstone, xi. 305.)

Spectra of Flames and Incandescent bodies.

Incandescent solids and liquids give continuous spectra without an spaces. Flames, *i.e.*, incandescent gases or vapours, give spectra consi bands, more or less numerous, with dark spaces between. An alcohol of a Bunsen's burner in which common salt or other volatile sodiu ignited, gives a spectrum reduced to a narrow yellow band, coincident line D. Lithium ignited in a similar manner exhibits a single brigh near the solar C. The potassium-spectrum, similarly produced, consist coinciding with A, and a violet band not coinciding with any of the lines, the intermediate portion of the spectrum being filled up with a The thallium spectrum consists of an intense green line near the solar li split up by Gassiot's train of eleven sulphide-of-carbon prisms into three The spectra of the alkaline earths are equally definite, though mor (See Analysis, Inorganic; also Spectral Analysis.)

In some cases, new series of bands become visible as the temperature r spectrum of chloride of lithium in the flame of a Bunsen burner, giv intense crimson line; in a hotter flame, as that of hydrogen, it gives orange ray; and in the oxy-hydrogen jet and in the voltaic arc, a broad band likewise comes out. A similar effect is perceived in the case of m thallium, and other metals when heated by the voltaic arc. A. Mitsch Ann. cxvi. 499) has shown that in flames of low temperature, the lines with the compound employed, the spectrum then observed being that d pound, and not to its elementary constituents; the spectrum of copper differs considerably from that of an alcoholic solution of chloride of cop from an alcoholic solution of iodide of copper differs from both.

Spectra of the Electric Light.—The spectrum of the electric light e lines like those of flames. This was first observed by Wollaston, Fraunhofer, who found that the line of bluish light obtained by d electricity of a machine through a very fine wire, gave a spectrum con bright line in the green. Wheatstone has shown that the electric l voltaic battery, the ordinary electric machine, and the induction coil, y spectra when the spark passes between conductors of the same kind; b and position of the lines varies with the nature of the metallic poles; if t of an alloy, two systems of lines are obtained, one belonging to each the same is also the case when the two poles are formed of different m facts show plainly that the electric spark contains particles of metal deta conductors between which it passes.

Masson, in the course of his researches on electric photometry, already examined the spectra produced by various metals when employed as a Leyden jar, and when heated by the voltaic arc, and found them to c greater number of lines than those of the same metals delineated by W The difference was subsequently explained by Angström (Phil. Mag. who showed that Masson, in consequence of the intense heat of the elec which he employed, obtained two spectra, one due to the metal, the atmosphere itself, which became ignited. Certain lines observed by M mon to the spectra of all the metals, were really those atmospheric lines the spark to pass between the same metals immersed in various gases, lines due to the metal remained unaltered, whilst the others due t medium, disappeared and were replaced by new lines.

For further details, and for the methods of examining the spectra incandescent bodies, see Spectral Analysis.

Kirchhoff's theory of the Lines in the Solar Spectrum. The vapour of absorbs rays of the same degree of refrangibility as those which are e same substance in the state of incandescence, that is to say, those w bright lines of its spectrum. Thus ignited sodium emits a yellow light of which consists of two bright bands coincident with the double line spectrum. If now, through a flame coloured by sodium, the light of the oxy-hydrogen flame, or that of the voltaic arc between carbon-po

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n produced by either of these sources is interrupted by
he solar line D. In like manner the spectra of po-
ntium and copper, may be *reversed*. On these facts
n of Fraunhofer's lines. He supposes that the luminous
the sun contains the vapours of various metals, and
atmosphere is the still more intensely heated solid or
emits light of all degrees of refrangibility, and would
were it not that some of the rays, in passing through
vapours which are themselves capable of emitting rays
bility, so that Fraunhofer's lines are only the reversed
ble if the more intensely heated nucleus were not there.
he solar spectrum with those of various metals, has
dark lines coincident with certain bright lines in the
nagnesium, calcium, iron, chromium, and nickel: hence
atmosphere contains these metals, and possibly also
but not lithium, copper, or silver. Angström is of
hydrogen and aluminium may also be considered as
rontium are probably also present. (See Kirchhoff's
n and on the Spectra of the Chemical Elements, trans-
cle Spectral Analysis in this Dictionary.)

ive Powers of different Media.

e rays of the spectrum, and consequently the length of
ferent media, exhibits great diversity. Suppose three
ter, the second of crown-glass, and the third of flint-
es as to produce equal deviations for any given ray of
out the middle: then it will be found that the crown-
the flint-glass spectrum $3\frac{1}{2}$ times as long as the water
flint-glass disperses the different coloured rays much
wn-glass much more than water.
dispersion produced by different media for the same
ray, which renders it possible to form achromatic com-
The object of such combinations is to reproduce white
ired rays which have suffered dispersion; and this is
ich have been dispersed by one lens or prism through a
acts them the contrary way (see *fig.* 665, p. 619). But
ng media dispersed the rays equally for a given amount
ay of effecting this would be to give the two prisms
e *fig.* 665), or the two lenses (one convex, and the
; but in this case all the rays would be brought back to
e or divergence as they had before passing through the
combination would act just like a plate of glass with
uce no alteration in the direction of the rays. But
of crown- and the second of flint-glass, to be placed
their refracting angles to be so proportioned as to
middle ray of the spectrum; then, as already observed,
rays about twice as much as the crown; and if instead
so adjusted as to produce equal amounts of dispersion,
hen the angle of the second must be of such a magnitude
than the crown-glass prism does. Such a combination
s and reproduce white light, without bringing back the
n. In like manner, if a concave lens of flint-glass be
crown-glass, its curvature may be so adjusted as to re-
estroying the convergence of the rays produced by the

dices of refraction of the extreme rays of the spectrum
ne fixed lines B and H, produced by any refracting me-
t of dispersion, or simply the dispersion of that

teen substances placed in the order of their coefficients
Vollaston, the most dispersive being placed first; *Sulphur*,
f turpentine, *Iceland-spar*, *diamond*, *crown-glass*, *water*,
ar, *rock-crystal*, *fluor-spar*. The most dispersive of all
horus, then a solution of phosphorus in sulphide of
itself (see p. 629).
ion is applied to the difference of the refractive indices

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of any other two colours, the red and yellow, blue and green, &c., alwa
principal fixed line belonging to each colour. The partial dispersions
stances are by no means proportional to their total dispersions; conseq
are not distributed in the same manner in the spectra formed by the t

Sulphuric acid and oil of cassia, for example, produce spectra of nea
but in the oil of cassia spectrum, the least refrangible portion—namely
and yellow—is much less, and the more refrangible portion, from blue
more expanded than in that produced by sulphuric acid. In like m
contracts the less, and expands the more refrangible portion of the spec
extent than crown-glass. This irrationality of dispersion must of cou
in the formation of achromatic combinations.

The ratio of dispersion of two media is the ratio of the coefficie
$\frac{\mu_v - \mu_r}{\mu'_v - \mu'_r}$, or of the partial coefficients belonging to the corresponding
two spectra. This ratio has different values according to the two line
sidered.

The term dispersive power is applied to the ratio of the dispers
the index of refraction of the mean ray diminished by 1. Taking as
line E in the yellow, and calling its index of refraction μ_y, the dispers
pressed by the formula, $\frac{\mu_v - \mu_r}{\mu_y - 1}$.

The following table contains the refractive indices of several media
lines of the spectrum, as determined by Fraunhofer; the last column
efficients of dispersion between the lines B and H:

Refracting substances.	B.	C.	D.	E.	F.	G.
Flint-glass, No. 13 . .	1·62775	1·62968	1·63503	1·64202	1·64826	1·6602
Crown-glass, No. 9 . .	1·52583	1·52685	1·52958	1·53300	1·53605	1·5416
Water	1·33093	1·33171	1·33358	1·33585	1·33782	1·3412
Solution of potash . .	1·39963	1·40051	1·40280	1·40563	1·40808	1·4125
Oil of turpentine . .	1·47049	1·47153	1·47443	1·47835	1·48173	1·4882
Flint-glass, No. 3 . .	1·60204	1·60380	1·60849	1·61453	1·62004	1·6307
,, No. 30 . .	1·62357	1·62547	1·63058	1·63735	1·64346	1·6554
Crown-glass, No. 13 . .	1·52431	1·52530	1·52788	1·53137	1·53434	1·5399
,, letter M . .	1·55477	1·55593	1·55907	1·56351	1·56674	1·5735
Flint-glass, No. 23 . .	1·62659	1·62847	1·63367	1·64049	1·64675	1·6588

Babinet has given a method of measuring the dispersions of bodies
be procured in small fragments. The substance being cut into the f
and its angle measured, a spectrum projected on a screen by a prism
is viewed through the small prism whose dispersion is to be determ
manner as to recompose the colours (p. 619), the observer graduall
distance from the spectrum till he sees nothing but white light. If t
the position of least deviation, and their angles are not too large, thei
to one another in the inverse ratio of their distances from the screen.

Gladstone and Dale have made an extensive series of researches o
dispersion, and sensitiveness of liquids, the last term being used to si
between the change of refraction and the change of volume by heat. T
the principal results obtained:

1. *Both refraction and dispersion diminish as the temperature inc*
has been verified by observations on about 90 liquids (see p. 626).

The following table exhibits these results in the case of a highly di
it will be observed that the sensitiveness of the rays increases in the o
frangibility.

Refractive Indices of Sulphide of Carbon for the several Fixed

Temperature.	Refractive Indices.					
	A.	B.	D.	E.	F.	
11°	1·6142	1·6207	1·6333	1·6465	1·6584	1·6
36·5	1·5945	1·6004	1·6120	1·6248	1·6362	1·6
Difference .	0·0197	0·0203	0·0213	0·0217	0·0222	0·0

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refraction by heat with the corresponding change of water, methylic, ethylic, and amylic alcohols, acetone, utyric ethers, methylic and ethylic iodides, salicylate e, xylene, cumene, nitrobenzene, hydrate of phenyl, nd Portugal, and eugenic acid, it was found that the — 1), multiplied into the volume, gives very nearly a mperatures. The quantity $\mu - 1$ is termed by the y of a substance, and this multiplied into the volume, rmed the specific refractive energy. The pre- as follows:—*The refractive energy of a body varies e influence of change of temperature; or in other words, liquid is a constant not affected by temperature.* The renders this law not absolutely accurate in the observed rsion does not follow the same law, the spectrum con- e, and in other cases much less rapidly as the volume as yet discoverable between change of dispersion and

nixed liquids, appear to show that *the specific refrac- ean of the specific refractive energies of its components.* e of carbon and ether, substances which are almost at nd were found to mix without condensation; also with hich, however, some diminution of volume occurs. In l numbers were slightly below those deduced from the ergies; yet no other formula could be devised which on to the indices actually observed.

same homologous series exhibit a progressive change in y advance in the series; but the deviation and extent her substances with which the radicle is combined. If, al indices, but these minus unity divided by the specific rease as the series advances.

is with regard to various groups of compounds con- C^{2n+1}.

ecific Refractive Energy.

Ether of acid.	Form- ate.	Ace- tate.	Buty- rate.	Oxa- late.	Mercury- com- pound.	Stannic com- pound.	Hy- dride.
·3905	. .	. .	. .	. .	·1707	·3727	
·4127	·3905	·4152	·4402	·3502	·2112	·3876	
·4333							
·4402							
·4492	·4432	·4506	·4724	·4306			
·4750	. .	. .	. .	. .	. .	. .	·5499
. .	. .	. .	. .	. .	. .	. .	·5522
·4890							

Specific Dispersion.

lide.	Ether of acid.	Acetate.	Mercury- compound.	Stannic compound.	Hydride.
09	168	. .	140	256	
18	178	178	170	268	
35	191				
.	191				
24	198	198			
.	. .	. .	. .	. .	242
.	. .	. .	. .	. .	236

f homologous bodies, it was found that benzene, benzy- e, gave nearly the same numbers, and no regular pro- itidine, and collidine showed an augmentation of the diminution of the specific dispersion with the advancing the most refractive organic liquid known) showed an roperties by addition of CH^2. Hence it appears that ement on the rays of light differs in different groups, oiling point.

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4. *Isomeric bodies are sometimes widely different in their* *many cases, especially where there is close chemical relationsh* *this respect.* Several hydrocarbons of the type $C^{10}H^{16}$, f to be identical in actual refractive power, notwithstanding sl In dispersion there are some variations, but not in sensitiven however, of the same ultimate composition, but differing properties differ also optically. Metameric compound of ethyl and acetate of amyl, are optically identical. Ani empirically C^6H^7N, are totally different.

5. *Effect of Chemical Substitution.*—When hydrogen is rep there is generally an increase of the actual refraction and dispe increased weight, hydrogen having a very low actual, but a v on the rays of light. When two substitution-products are f the same element in a given compound, *e.g.* mono- and tri-ch the lower one always retains, in its optical properties, a posit the original substance and the higher product.

From these facts, it may be inferred, as approximately, if *Every liquid has a specific refractive energy composed of the* *of its component elements, modified by the manner of combi* *change of temperature; and this refractive energy accompanies* *liquids.* The product of the specific refractive energy and temperature, is, when added to unity, the refractive index.

The following tables exhibit the numerical results from w clusions are deduced.

TABLE A.

Refractive indices of the lines A, D, H *at different*

The sign ? attached to a liquid denotes that the purity of the specimen i
An asterisk * attached to a degree of temperature signifies that the obs
were made on a different occasion to the observations at other temperatu
Specific gravities not determined from the specimens examined are incl

No.	Liquid.	Specific gravity.	Temperature of observation.	
1.	Methylic alcohol . . .	0·7972 at 20°C.	20°	1
			37	1
2.	Ditto from oxalate . .	0·7960 at 20	20	1
			29·5	1
3.	Amylic alcohol . . .	0·8179 at 15·5	24·5	1
			41	1
4.	Caprylic alcohol . . .	0·8214 at 15·5	27	1
			47	1
5.	Iodide of methyl . .	2·1912 at 20	23·5	1
			29·5	1
6.	Iodide of ethyl . . .	1·9228 at 20	23·5	1
			36	1
			48	1
7.	Iodide of trityl . . .	1·7117 at 20	8·5	1
			20	1
			30	1
8.	Iodide of amyl . . .	1·4950 at 20	17·5	1
			37	1
9.	Formic ether . . .	0·9088 at 20	22	1
			31	1
			40	1
10.	Acetic ether . . .	0·8648 at 20	20	1
			28	1
11.	Acetic ether . . .	0·8972 at 20	23·5	1
			33	1
			41	1
12.	Propionic ether . . .	0·8555 at 20	22·5	1
			32	1
			42	1

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TABLE A—*continued.*

No.	Liquid.	Specific gravity.	Temperature of observation	Refractive indices. A.	D	H.
13.	Butyric ether	0·8778 at 20°C.	23	1·3850	1·3888	1·4018
			40	1·3768	1·3808	1·3933
14	Valerianic ether	0·8680 at 20	18	1·3916	1·3958	1·4089
			32·5	1·3856	1·3898	1·4024
15.	Acetate of amyl	0·8680 at 20	24·5	1·3910	1·3950	1·4081
			34·5	1·3867	1·3905	1·4037
			44	1·3817	1·3859	1·3985
16.	Ditto, second specimen		8·5	1 3944	1·3988	1 4113
			21·5	1·3886	1 3928	1·4058
			35	1·3820	1·3866	1·3990
17.	Acetate of octyl?		27·5	1·4045	1·4092	1·4255
			40	1·3972	1·4020	1·4181
18.	Hydride of heptyl	0·7090 at 20	9·5	1·3956	1·3996	1·4135
			22	1·3888	1·3931	1·4059
			36	1·3811	1·3854	1·3976
19.	Hydride of octyl	0·7191 at 20	9	1·4022	1·4065	1 4197
			28·5	1·3931	1·3972	1·4097
			41	1·3870	1·3911	1·4032
20.	Mercuric methyl?	(3·069)	8·5*	1·5274	1·5378	1·5726
			15·5*	1·5262	1·5355	1·5694
			26·5	1·5197	1·5296	1·5626
21.	Mercuric ethyl?	(2·444)	8·5*	1·5300	1·5397	1·5729
			24·5	1·5124	1·5217	1·5538
22.	Stannic ethyl-methyl?	1·2220 at 20	19	1·4555	1·4625	1·4868
			34·5	1·4479	1·4747	1·4783
23.	Stannic ethyl?	1·1920 at 20	23	1·4606	1·4673	1·4905
			35	1·4551	1·4621	1·4844
			48	1·4481	1·4549	1 4769
24.	Triethylarsine		19·5	1·4598	1·4669	1·4919
			26·5	1·4588	1·4657	1·4906
25.	Acetic acid	1·0592 at 20	24	1·3674	1·3718	1·3846
			34·5	1·3635	1·3680	1·3803
			45	1·3596	1·3634	1·3757
26.	Acetone	0·8117 at 15·5	25·5	1·3540	1·3580	1·3706
			40	1·3469	1·3512	1·3631
27.	Amylene	0·7151 at 20	23	1·3832	1·3878	1·4028
			35	1·3786	1·3834	1·3982
28.	Carbonic ether	0·9720 at 20	22	1·3773	1·3810	1·3936
			31	1·3746	1·3787	1·3898
			40	1·3692	1· 734	1·3846
29.	Boracic ether	0·8760 at 20	22·5	1·3664	1·3698	1·3815
			40·5	1·3578	1·3604	1·3724
30.	Silicic ether	0·9320 at 20	20	1·3781	1·3821	1·3940
			33·5	1·3724	1·3768	1·3881
31.	Salicylate of methyl	1·1760 at 20	21	1·5206	1·5319	1·5810
			37	1·5140	1·5253	1·5735
32.	Nitrate of amyl	1·0008 at 20	10	1·4109	1·4157	1·4320
			22·5	1·4053	1·4097	1·4256
			36·5	1·3988	1·4035	1·4191
33.	Chloroform	1·4980 at 20	18	1·4411	1·4463	1·4630
			30	1·4346	1·4397	1·4561
			44	1·4253	1·4308	1·4471
34.	Bromoform	2·6360 at 12	15·5	1·5579	1·5674	1·5998
			29	1·5505	1·5598	1·5921
			39	1·5437	1·5531	1·5846
35.	Dutch liquid		21	1·4175	1·4221	1·4371
			38	1·4082	1·4126	1·4276
36.	Dibromide of bromethylene	2·6160 at 20	18	1·5819	1·5915	1·6249
			39·5	1·5701	1·5787	1·6112
37.	Dibromide of chlorethylene	2·2477 at 20	13	1·5477	1·5559	1·5839
			24	1 5413	1·5494	1·5770

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TABLE A—*continued.*

No.	Liquid.	Specific gravity.	Temperature of observation.	Ref A.
38.	Dichloride of chlorethylene .	1·4177 at 20°C.	13	1·4661
			29·5	1·4563
39.	Benzene	0·8667 at 20	10·5	1·4879
			23	1·4806
			39	1·4703
40.	Parabenzene . . .	0·8469 at 20	20	1·4814
41.	Benzylene	0·8650 at 20	25·5	1·4709
			32·5	1·4672
			39	1·4629
42.	Parabenzylene . . .	0·8333 at 20	28	1·4667
			40	1·4590
43.	Benzylene	0·8658 at 20	14	1·4869
			33	. .
44.	Xylene	0·8660 at 20	11	1·4888
			28	1·4788
			42	1·4716
45.	Cumene (from cuminic acid)	0·8710 at 20	7	1·4898
			27·5	1·4783
46.	Cumene (from impure wood-spirit) . . .	0·8580 at 20	8·5	1·4687
			24	1·4608
			34	1·4555
47.	Pseudocumene . . .	0·8692 at 20	12·5	1·4843
			35·5	1·4728
48.	Cymene	0·8610 at 20	8	1·4760
			29	1·4648
49.	Cymene (from camphor) .	0·8565 at 20	12	1·4731
			26	1·4659
			36	1·4614
50.	Chlorobenzene . . .	1·1080 at 20	9	1·5194
			27·5	1·5095
51.	Trichlorobenzene . .	1·4500 at 20	20	1·5563
			37	1·5495
52.	Nitrobenzene . . .	1·1590 at 20	25	1·5331
			38	1·5266
53.	Dinitrobenzene in 2 equivs. of nitrobenzene .	1·2670 at 20	23·5	1·5460
			35	1·5404
			56	1·5296
54.	Aniline	1·0270 at 16	21·5	1·5644
			37	1·5567
			42	1·5537
			47	1·5520
55.	Amyl-aniline . . .	0·9177 at 20	23·5	1·5114
			42	1·5035
56.	Hydrate of cresyl . .	1·0364 at 20	11·5	1·5341
			32	1·5281
57.	Pyridine	0·9738 at 20	21·5	1·4940
			36	1·4860
58.	Picoline	(0·955)	22·5	1·4188
			37·5	1·4803
			52	1·4718
59.	Lutidine	(0·936)	8·5*	1·4932
			22·5	1·4894
60.	Collidine	(0·921)	23·5	1·4927
			45	1·4820
61.	Chinoline	(1·0810 at 10)	24	1·5567
			35	1·5466
			37	1·5496
62.	Lepidine	1·0720 at 15	21	1·6039
			47	1·5909
63.	Hydrocarbon from anise .	0·8580 at 20	11	1·4653
			30	. .

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TABLE A—*continued.*

No.	Liquid.	Specific gravity.	Temperature of observation.	Refractive indices. A.	D.	H.
64.	Hydrocarbon from turpentine	0·8644 at 20° C.	10*	1·4669	1·4734	1·4934
			24	1·4596	1·4653	1·4845
			47	1·4487	1·4545	1·4730
65.	„ „ carraway	0·8529 at 20	14	1·4640	1·4701	1·4901
			37	1·4529	1·4589	1·4783
66.	„ „ thyme	0·8635 at 20	25	1·4594	1·4652	1·4856
			35·5	1·4545	1·4606	1·4805
67.	„ „ bay	0·8510 at 20	23	1·4545	1·4610	1·4818
			43	1·4468	1·4528	
68.	„ „ bergamot	0·8467 at 20	26·5	1·4574	1·4640	1·4865
			38	1·4517	1·4578	1·4800
69.	„ „ cloves	0·9041 at 20	17	1·4918	1·4985	1·5209
			28·5	1·4870	1·4936	1·5157
			39	1·4828	1·4892	1·5110
70.	„ „ cubebs	0·9270 at 20	10·5	1·4988	1·5055	1·5294
			20	1·4950	1·5014	1·5252
			31	1·4905	1·4977	1·5209
71.	Carvene	0·9530 at 20	12·5	1·4913	1·4992	1·5270
			24·5	1·4862	1·4935	1·5196
			34	1·4812	1·4884	1·5145
72.	Eugenic acid	1·0640 at 20	18	1·5285	1·5394	1·5780
			27·5	1·5244	1·5347	1·5722
73.	Camphor of peppermint	0·8786 at 43	30	1·4503	1·4553	1·4703
			43	1·4451	1·4505	1·4653
74.	Glycerin	1·2610 at 17	20	1·4659	1·4705	1·4850
			30	1·4634	1·4680	1·4823
			48	1·4586	1·4631	1·4773
75.	Nitroglycerin?	(1·60)	13·5	1·4683	1·4749	1·4947
			32·5	1·4596	1·4662	
76.	Nicotine	1·0260 at 18	18	1·5149	1·5234	1·5542
			32	1·5107	1·5194	1·5493
77.	Tribromide of phosphorus	2·880 at 20	25	1·6698	1·6866	1·7506
			36	1·6627	1·6792	1·7422
78.	Trichloride of phosphorus	1·4530 at 20	25·5	1·5030	1·5118	1·5418
			38	1·4957	1·5042	1·5334
79.	Oxychloride of phosphorus	1·6800 at 20	17	1·4810	1·4882	1·5118
			26	1·4756	1·4832	1·5067

TABLE B.

Refractive Indices.

The liquids in this table are arranged according to their power of refracting the line A at 20° C.

Liquid.	Temp.	Refractive indices. A.	B.	C.	D.	E.	F.	G.	H.
Phosphorus	35° C.	2·0389	. .	. .	2·0746	. .	2·1201	2·1710	2·2267
Phosphorus in sulphide of carbon	?	1·9209	1·9314	. .	1·9527	1·9744	1·9941	2·0361	2·0746
Tribromide of phosphorus	25	1·6698	1·6752	. .	1·6866	. .	1·7083	1·7300	1·7506
Sulphide of carbon	11	1·6142	1·6207	1·6240	1·6333	1·6465	1·6584	1·6836	1·7090
Lepidine	21	1·6039	1·6094	. .	1·6189	. .	1·6403	1·6615	1·6822
Dibromide of bromethylene	18	1·5819	1·5851	. .	1·5915	. .	1·6037	1·6149	1·6249
Rectified oil of cassia	28	1·5649	1·5699	1·5727	1·5801	1·5909	1·6014	1·6244	
Aniline	21·5	1·5644	1·5684	. .	1·5774	. .	1·5951	1·6125	1·6297
Chinoline	24	1·5567	1·5617	. .	1·5687	. .	1·5879	1·6030	1·6198

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Table B—

Liquid.	Temp.	A.	B.
Trichlorobenzene	20°C.	1·5563	1·560
Bromoform	15·5	1·5579	1·561
Dinitrobenzene in nitrobenzene	23·5	1·5460	1·550
Dibromide of chlorethylene	12·5	1·5472	1·550
Nitrobenzene	25	1·5331	1·537
Hydrate of phenyl	13	1·5377	1·541
Hydrate of cresyl	11·5	1·5341	1·537
Eugenic acid	18	1·5285	1·532
Mercuric methyl	26·5	1·5197	1·523
Salicylate of methyl	21	1·5206	1·524
Iodide of methyl	16	1·5203	1·523
Mercuric ethyl	8·5	1·5300	1·533
Nicotine	18	1·5149	1·517
Chlorobenzene	9	1·5194	1·522
Amyl-aniline	23·5	1·5114	1·515
Trichloride of phosphorus	23·5	1·5052	1·508
Iodide of ethyl	23·5	1·5003	1·503
Rectified oil of santalwood	25·5	1·4954	1·497
Hydrocarbon from cubebs	10·5	1·4988	1·501
Pyridine	21·5	1·4940	1·496
Lutidine	22·5	1·4894	1·492
Collidine	23·5	1·4927	1·495
Hydrocarbon from cloves	17	1·4918	1·494
Pseudocumene	12·5	1·4843	1·487
Iodide of amyl	17·5	1·4816	1·484
Oxychloride of phosphorus	17	1·4810	1·484
Benzene	10·5	1·4879	1·491
Benzylene	14	1·4869	1·489
Cymene	29	1·4648	1·467
Nitroglycerin	13·5	1·4683	1·470
Hydrocarbon from Portugal	25	1·4617	1·464
Cumene (2nd specimen)	8·5	1·4687	1·470
Stannic ethyl	23	1·4606	1·462
Dichloride of chlorethylene	13	1·4661	1·468
Hydrocarbon from turpentine	24	1·4596	1·461
Hydrocarbon from carraway	24	1·4594	1·461
Hydrocarbon from bergamot	26·5	1·4574	1·459
Rectified oil of citronella	19	1·4598	1·461
Hydrocarbon from bay	23	1·4545	1·456
Stannic ethyl-methyl	19	1·4555	1·457
Chloroform	10	1·4438	1·445
Octylic alcohol	9·5	1·4230	1·424
Nitrate of amyl	10	1·4109	1·412
Amylic alcohol	25	1·3981	1·399
Hydride of octyl	9	1·4022	1·403
Hydride of heptyl	9·5	1·3956	1·396

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Table B—*continued.*

Liquid.	Temp.	Refractive indices.							
		A.	B.	C.	D.	E.	F.	G.	H.
Acetate of amyl	8·5 C.	1·3944	1·3958	. .	1·3998	. .	1·4035	1·4077	1·4113
Butyric ether	23	1·3850	1·3864	. .	1·3888	. .	1·3938	1·3981	1·4018
Amylene	8	1·3850	1·3866	. .	1·3896	. .	1·3944	1·3992	1·4033
Carbonic ether	22	1·3773	1·3785	. .	1·3810	. .	1·3856	1·3896	1·3936
Propionic ether	22·5	1·3696	1·3713	. .	1·3736	. .	1·3785	1·3827	1·3860
Boracic ether	22·5	1·3664	. .	. .	1·3698	. .	1·3742	1·3785	1·3815
Acetic ether	20	1·3645	1·3658	. .	1·3685	. .	1·3728	1·3766	1·3798
Alcohol	15	1·3600	1·3612	1·3621	1·3638	1·3661	1·3683	1·3720	1·3751
Acetone	25·5	1·3540	1·3554	. .	1·3582	. .	1·3629	1·3670	1·3706
Formic ether	22	1·3540	1·3553	. .	1·3582	. .	1·3627	1·3666	1·3694
Ether	15	1·3529	1·3545	1·3554	1·3566	1·3590	1·3606	1·3646	1·3683
Water	15	1·3284	1·3300	1·3307	1·3324	1·3347	1·3366	1·3402	1·3431
Methylic alcohol	20	1·3264	1·3277	. .	1·3299	.	1·3330	1·3669	1·3395

Cause of Dispersion.—As the several colours correspond to vibrations of different rapidity, and the deviation of rays of light in refraction depends on the change of velocity of light in passing from one medium into another, it follows that in order to explain dispersion, we must suppose that this change of velocity is different for rays of different colours, that is to say, that waves of different length travel through refracting media with different velocities. This consequence was for a long time regarded as a grave objection to the undulatory theory of light, being in fact in contradiction to the general formula for the velocity of undulations established by Newton, viz. $v' = \frac{e}{d}$. It must, however, be remembered that though the velocity of light in free space is the same for rays of all colours (p. 594), it is by no means necessarily so in transparent media, which retain the ether imprisoned, as it were, between their particles. The waves must then turn round these molecules, and it is easily conceivable that the retardations thus produced may be greater for the shorter than for the longer undulations. That such is the case has in fact been proved by the analytical researches of Cauchy; but the demonstration is not of a character to be introduced into this work, and does not admit of representation in a more elementary form.

Heating, Chemical, and Phosphorogenic Rays of the Spectrum.

All the rays of the solar spectrum are capable of giving heat as well as light. A thermometer held in any part of the spectrum indicates a rise of temperature; but the heating effect is very different in different parts, being greatest at the red end of the spectrum; but the particular position of the maximum heating effect varies with the kind of prism used. Moreover, there are invisible heat-rays situated beyond the red, and therefore of lower refrangibility than any of the luminous rays; and when a flint-glass prism is used, the maximum of heating power is situated beyond the visible red rays.

The spectra of flames exhibit similar results, provided the heat-rays which they emit are capable of passing through the substance of which the prism is formed, which is not always the case. (See RADIATION OF HEAT.)

The solar rays are also capable of producing chemical change, chiefly of the reducing order. Thus silver-salts are blackened and more or less reduced by exposure to daylight, and the leaves of plants, under the influence of sunlight, decompose the carbonic acid in the air, and assimilate its carbon. This action is exerted by all the luminous rays of the spectrum, but chiefly by the violet rays, and by non-luminous rays extending to a considerable distance beyond the violet. The yellow and red rays have but little chemical power: hence ordinary flames (hydrocarbon flames) in which these rays greatly predominate, exert but little action on chloride of silver and other bodies, which change rapidly under the influence of solar light; and in monochromatic yellow flames, such as that of alcohol containing a sodium-salt, the chemical action is altogether imperceptible. Photographers develope their pictures in rooms into which light is admitted only through yellow glass or yellow paper. Violet flames, on the other hand, like that of burning magnesium, emit rays whose chemical activity rivals that of sunlight, though their luminosity is incomparably less. The maximum of chemical action is not, however, produced upon all substances in the same part of

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the spectrum. According to E. Becquerel (Ann. Ch. Phys
silver begins to blacken in the extreme violet between the
tion extending on the one side nearly to F, and on the othe
visible violet. With the iodide and bromide of silver, the
that the action does not extend so far beyond the violet,
not occupy the same place. Guaiac-resin, which is turn
sunlight, is not at all affected by any of the visible rays of
beginning only in the ultra-violet, and the maximum being s
the end of the visible spectrum.

The chemical spectrum contains fixed lines, that is to
chemical action is produced, so that when a piece of paper
silver or other sensitive substance has been exposed to the
surface is traversed by lines of the same colour as the origin
violet as well as in the visible portion of the spectrum. A d
be given in the next article on the CHEMICAL ACTION OF LIG

The interposition of *colourless plates* or *films* does not mod
the visible part of the spectrum between A and H; that of
is likewise unaltered by certain transparent substances, such
acid, &c., whereas other substances, both liquid and solid, w
of the most refrangible chemical rays situated beyond the v
a point more or less near to H. With nitric acid and oil
action stops at N; with creasote, bitter almond-oil, and a
sulphate of quinine, at H. (For further details respecting th
see the next article.)

The different rays of the spectrum also differ in their po
phorescence. When Canton's phosphorus spread on a sh
a dark room to the action of the spectrum, phosphorescence
between G and P (see figure in the next article); there is
beween I and N, and two maxima, one between H and
Bolognian phosphorus gives similar results, excepting that
I N, and only one maximum between I and M. It appears
phorogenic rays occupy the same portion of the spectrum as

The colour of the phosphorescent light, which may vary
has no relation to that of the exciting rays, excepting in the
sulphide of barium, which shines with an orange-yellow lig
posed to the rays between H and P, with a more reddish l
blue and violet rays; *sulphide of calcium*, which shines with
it has been exposed to the rays between F and O, and exhib
when the incident rays are comprised between O and P; last
by the action of sulphide of potassium on oyster-shells ca
emits a violet-indigo light after exposure to rays of the sa
in the ultra-violet rays. In general, the emitted rays are
exciting rays, the last-mentioned substance, however, forming

The *electric light*, which is very bright and very rich in
produces phosphorescence more actively than the solar rays.
more efficacious than the continuous light of the voltaic arc.

The phosphorogenic spectrum likewise exhibits dark lines
to see them it is necessary to extend the spectrum to about
by means of diverging lenses. Dark lines are then seen on t
occupying the same position as those of the luminous and
may be rendered more distinct by heating the phosphoresc
and 300°; the luminous portions then become brighter, and

Transparent substances, both coloured and colourless, pl
incident rays, absorb the phosphorogenic rays in the same pa
luminous and chemical rays.

Identity of the calorific, luminous, chemical, and phos
formerly supposed that the rays producing these several effe
other; in fact, that luminous bodies emit four kinds of ra
by a prism, form four spectra superposed over each other,
and minima at different places. But it is much more p
undulations are all of one kind, and capable of producing
above mentioned, according to the nature of the bodies or or
In fact, the calorific and chemical rays are reflected and refr
as luminous rays of equal refrangibility; the calorific, lumi
are interrupted by the same lines; and bodies which absorb
absorb heat-rays and chemical rays of the same degree of re
true with regard to the phosphorogenic rays, so far as they

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part of the spectrum. Moreover, Fizeau and Foucault have shown that the chemical actions produced at the focus of a lens by the light of the voltaic arc and the lime-light, are to one another in the same ratio as the luminous intensity.

The production of the several effects above mentioned by the same rays, is quite in accordance with the wave-theory of light. The waves of the ether striking on the surface of ponderable bodies throw their particles into vibration, and the particular effects produced are determined by the rate and mode of vibration thus excited, which themselves depend upon the manner in which the particles of the body are held together, as well as upon the rate of vibration of the incident waves. Rays whose length and rapidity of vibration are such as to excite in our organs the sensations of both heat and light, may, when they impinge upon a ponderable body, set its particles into such a rate of vibration as to excite in the surrounding ether, waves whose length and rapidity of vibration correspond to the least refrangible rays of the spectrum beyond the visible red. In like manner, we shall presently see that the invisible chemical rays at the other end of the spectrum may excite vibrations of less rapidity, which render visible the body on which they impinge. The effect thus produced is called

Fluorescence.

It was observed some years ago, by Sir John Herschel, that a solution of sulphate of quinine, though perfectly colourless by transmitted light, exhibits in certain aspects a peculiar blue colour. This blue light was found to be produced only by a very thin stratum of liquid adjacent to the surface by which the light entered, and the incident beam, after having passed through the stratum from which the blue light came, was not sensibly weakened or coloured, but had lost the power of producing the usual blue colour when admitted into another solution of sulphate of quinine. Light thus modified was said by Sir J. Herschel to be *epipolised*.

Similar phenomena were observed by Sir D. Brewster in an alcoholic solution of chlorophyll, the green colouring matter of leaves, the path of a beam of sunlight admitted into the green solution being marked by a bright light of a blood-red colour. The same appearance was afterwards observed in various vegetable solutions and essential oils, and in some solids. Brewster distinguished this phenomenon by the name of *internal dispersion*, attributing it to the irregular reflection of the light from coloured particles suspended in the liquid, and was of opinion that Herschel's epipolic dispersion was only a particular case of this internal dispersion.

The true explanation of these remarkable phenomena has, however, been given by Professor Stokes, who has shown that the peculiar dispersion produced by sulphate of quinine, and the other liquids above mentioned, is due *to a change of refrangibility in the rays of light*. The following experiment renders this evident:—

A solar spectrum is formed by means of an achromatic lens, and one or more prisms of flint glass, sufficiently pure to render visible the principal fixed lines, and a tube filled with a solution of sulphate of quinine is passed along this spectrum, from the red towards the violet end. Nothing peculiar is observed while the tube is held in the less refrangible part of the spectrum, the light passing through it freely and without sensible modification; but just before it reaches the extremity of the violet, a peculiar blue diffused light makes its appearance at the surface of the fluid by which the light enters, and remains visible, even after the tube has passed beyond the violet into the invisible portion of the spectrum, acquiring, in fact, its greatest intensity at a certain distance beyond the extreme violet.

The stratum of liquid from which the diffused blue light emanates is thinner in proportion as the incident rays are more refrangible; and, from a little beyond the extreme violet to the end of the spectrum, the blue space is reduced to an excessively thin stratum adjacent to the surface by which the rays enter. It appears, therefore, that the solution, though transparent with respect to nearly the whole of the visible rays, is of an inky blackness with respect to the invisible rays more refrangible than the violet. Nevertheless, these rays, when once they have been converted into the visible blue light, pass through the liquid with facility. They must, therefore, be essentially altered in character. Now, a change in the quality of light must consist, either in a modification of its state of polarisation, or in its period of undulation. The former supposition is excluded by the fact that the light thus modified is not polarised at all. It must, therefore, have undergone a change in its rate of vibration, and consequently a change of refrangibility. The existence of this change is, moreover, distinctly proved by examining the diffused light with a prism. It is then found to be by no means homogeneous, but to be resolvable into rays of unequal refrangibility, the whole of which are, however, comprised within the limits of the visible spectrum. *The diffused blue light consists of the chemical rays rendered visible by a change in their refrangibility.*

The diffusion thus produced is entirely distinct from that which is due to reflection

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from irregularities or suspended particles. The two phenc
together in the same medium; but they are easily distingui
light diffused by irregular reflection is more or less polarised
in the manner above described is entirely unpolarised, even
themselves polarised. This phenomenon, to which Professor
name of *true diffusion*, to distinguish it from the false diffus
reflection, is now called FLUORESCENCE.

It is exhibited by many solutions, and by many solid
transparent, the colour of the diffused light varying with t
An aqueous infusion of horse-chesnut bark exhibits it very
colour similar to that of sulphate of quinine. Many compo
nium are also highly fluorescent, and diffuse a greenish-
nitrate, and *canary-glass*. A decoction of madder mixed w
orange-yellow fluorescence; tincture of turmeric and alcoh
seeds diffuse a greenish light; an alcoholic solution of chlor

When the fluorescence is strong, as with sulphate of q
merely viewing the substance by ordinary diffused daylight.
vation and for detecting fluorescence when it exists onl
following method is recommended by Stokes (Phil. Mag.

Light is admitted into a darkened room through a hole se
the window-shutter, and the object to be examined is placed o
the top, and fixed just below. The hole is covered with a
the *principal absorbent*, so selected as to transmit only the
visible rays of high refrangibility. The body on the shelf is
medium, the *complementary absorbent*, which is chosen so
possible to those rays which are absorbed by the first, and t
are transmitted by the first. If the media are well selected
approach to perfect darkness; and if the object appears u
most probably arises from fluorescence. To determine w
really due to that cause, the complementary absorbent is rem
to the front of the aperture, when the illumination, if really
wholly disappears; whereas, if it be due merely to scattere
through both media, it remains. In examining feebly fluor
it is better to keep the second medium in its place before t
medium, the *transfer-medium*, placing the last alternately i
rays, and between the object and the eye. Still greater
attained by placing the substance side by side with a small w
is quite destitute of fluorescence, and examining the two
object being placed on the tablet, a slit is held close to it,
seen projected partly on the object, partly on the tablet, and
a prism. The fluorescence of the object is evidenced by ligh
the spectrum, in which the rays coming through the princip
by the tablet, then produce nothing but darkness. These m
to show the fluorescence of white paper, even on a very gloo

It is not merely the most refrangible rays that are capable
the rays of any part of the spectrum may undergo this chang
media with the spectrum in the manner already described,
cence begins, sometimes in the blue, sometimes in the yellow
tion of chlorophyll, it begins in the red. But wherever the cl
begin, it is always in one direction, consisting in a diminutio
and a consequent depression of the light in the scale of colo
length of the wave is increased, and its velocity of undulatio
tions of the ether in the incident ray appear to excite distur
molecules of the fluorescent medium, whereby new vibratio
differing in period from those of the incident ray. The port
produced this molecular disturbance is used up or *absorbed*,
perception, just as heat is converted into mechanical work.
sorption of light always takes place in this manner. The w
version of luminous rays into invisible calorific rays, is, as s
instance of diminution of refrangibility accompanied by abs

As the most refrangible rays are the most active in p
natural that this effect should be most strikingly exhibited
are rich in those rays,—the flame of alcohol and of sulphur,
do, in fact, produce the effect in a higher degree even than
beautiful effect is produced by exposing a number of highly
sulphate of quinine, infusion of horse-chesnut bark, and ca
sulphur burning in oxygen in a dark room.

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The colour and composition of fluorescent light sometimes afford valuable aid in distinguishing between one substance and another, and in testing the purity of solutions. With a solution of a *pure substance*, the tint of the fluorescent light is almost perfectly constant. But this tint, it must be remembered, is that of the light *as emitted*, not as *subsequently modified* by absorption on the part of the solution, in case the solution be sensibly coloured, and some precautions are required in order to observe it correctly. The fluorescence observed in solutions from the barks of the horse-chesnut, ash, &c., was formerly attributed indiscriminately to the presence of æsculin, whereas a purified solution from the bark of the horse-chesnut exhibits a fluorescence very sensibly different from that of æsculin, which observation alone would suffice to show that the bark must contain some other fluorescent substance besides æsculin.

The best mode of observing the true fluorescent tint is to dilute the liquid considerably, and to pass into it a beam of sunlight, condensed by a lens fixed in a board in such a manner that as small a thickness of the liquid as possible shall intervene between the fluorescent substance and the eye. If a stratum of this thickness of the dilute solution is sensibly colourless, the tint of the fluorescent light will not be sensibly modified by subsequent absorption. But as direct sunlight is not always to be had, the following method, requiring only diffused daylight, may also be used, the solutions being pretty strong, or at least not extremely dilute.

A glass containing water and blackened internally at the bottom is placed at a window, and the solution to be examined as to its fluorescent tint is placed in a test-tube which is held vertically in the water, the top slightly inclining from the window, and the observer regarding the fluorescent light from above, looking outside the test-tube. Since by far the greater part of the fluorescent light comes from a very thin stratum of liquid next the surface by which the light enters, the fluorescent rays have mostly to traverse only a very small thickness of the coloured liquid before reaching the eye; the water permits the escape of those fluorescent rays which would otherwise be internally reflected at the external surface of the test-tube, and the intensity of the light of which the tint is to be observed is increased by foreshortening. (Stokes, Chem. Soc. J. xi. 19.)

The nature of the solvent must also be attended to. The colour of the fluorescent light is liable to change, not merely in passing from an alkaline to a neutral or acid solution, but even occasionally in passing from one neutral solvent to another.

The composition of fluorescent light, as revealed by the prism, occasionally presents peculiarities, but in such cases they are found to be connected with peculiarities in the mode of absorption, so that the two are not to be regarded as *independent* characters of a substance; and as the peculiarities in the absorption are, as a general rule, the more easily observed, it is only rarely that the analysis of the fluorescent light is of much use.

The distribution of fluorescence in the spectrum often affords valuable information, but its observation requires the use of somewhat complicated apparatus. The observation is restricted to times when the sun is shining pretty steadily (unless the observer has recourse to electric light, or at least lime-light); it is requisite to reflect the sun's light horizontally, without which the observation would be most troublesome; and unless the reflexion be made by the mirror of a heliostat, the continual change in the direction of the reflected light is most inconvenient. It is requisite to use at least one good prism, better two or three, which must be of tolerable size, in order to have light of sufficient intensity, and the prisms must be combined with a lens, which need not however be achromatic.

It has already been stated, as the result of experience, that the colour of the fluorescent light of a single substance is constant throughout the spectrum, or very nearly so. If, therefore, on examining a solution in a pure spectrum thus formed by projection, we find the fluorescence taking a fresh start *with a different colour*, we may be almost certain that we have to do with a mixture of two different fluorescent substances, the presence of which is thus revealed without any chemical process. If, however, the fluorescence of two fluorescent substances, which may be mixed together, begins at nearly the same point in the spectrum (as commonly happens when there is merely a slight difference of tint in the colour of the fluorescent light of the two substances), the coexistence of the two may escape detection when the mixed solution is merely examined in a pure spectrum; and in such cases a combination of processes of fractional separation with the observation of the tint of the fluorescent light is more searching. This is the case, for instance, with the mixture of æsculin and fraxin contained in a solution from the bark of the horse-chesnut.

As the occurrence of a decided difference of colour in the fluorescent light seen at two different parts of the spectrum implies, almost to a certainty, the presence of two different fluorescent substances, so, conversely, the exhibition of the same colour is an argument in favour of the identity of the substance producing the fluorescence at the

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two parts. We cannot, indeed, say that there may not be tw
fluorescence of which commences at nearly the same part o
different substances, the fluorescence of which commenced at
of the spectrum, would certainly reveal themselves by the
experience shows that the refrangibility of the light emitted
spectrum, by the solution of a pure substance, extends near
of the incident spectrum at which the fluorescence commence
and though, in passing from one pure substance to another,
relative brightness of the rays of less refrangibility which
light, yet, on the whole, there is so close a connection b
fluorescent light and the refrangibility of the rays by whic
produced, that a great variation in the one is incompatible
trifling variation in the other. (Stokes, Chem. Soc. J. xvii

Absorption.

All bodies are transparent to a certain extent; even me
opaque of all substances, allow a small quantity of light to
they are reduced to extremely thin leaves; thus gold-leaf
light of a green colour. On the other hand, there is no
transparent medium; even the air stops a certain quantity of
traversed by the rays is very considerable; on the tops of
appear much brighter than when seen from near the sea
thicknesses, however, colourless gases may be regarded as pe

Transparent media are colourless or coloured, according as
rays composing white light, in the same or in different propo
is one which transmits the red rays more easily than those
viewing a solar spectrum through a piece of glass 1 millim
red oxide of copper, all the colours excepting the red disappe
to all the more refrangible rays. Other media transmit ray
and stop the rest, and consequently exhibit compound colou
thus an ammoniacal solution of copper, when of a certain
stops all the rays excepting the red and the violet.

If rays which have passed through a red glass be passed
the same colour, the latter will absorb but a small proportion
upon it, because those which are incapable of passing throug
been eliminated by the first medium; but if the second glass
red rays, and the two together will form a perfectly opaque s

There is no medium which is absolutely colourless, that is
mitting rays of all colours in exactly the same proportion; eve
great thicknesses, appears blue; the colour of the sky is merel
seen through a thickness of several miles; in like manner d
blue, just as if they were seen through a blue glass.

On the other hand, to enable a medium to absorb the ray
completely, it must have a certain thickness. Even metals, s
reduced to extremely thin films, transmit certain colours, an
when of a certain thickness, stops all but the red rays of t
greater and greater number of coloured rays as its thickness
appears almost colourless.

It was formerly supposed that the quantity of light abso
the thickness of the medium through which it passed, but lat
that the law is more complicated. Suppose the medium di
layers perpendicular to the direction of the rays which trav
fraction, supposed constant, which represents the proportion
light arriving at any layer, and that of the light which pas
The quantity of light (supposed homogeneous) which arrives
that which reaches the second will be Ia; that which arrives
and so on. If therefore e represents the thickness of the mediu
the intensity of the ray after having passed through this t
formula $i = Ia^e$. The intensity of the emergent light decrea
proportion, while the thickness of the medium increases i
The quantities absorbed by the successive layers follow a si
first layer $I - Ia = I(1-a)$; for the second, $Ia(1-a)$; for
for the nth, $Ia^{n-1}(1-a)$.

Now let R, O, Y, &c., represent the intensities of the seve
posing a ray of incident light, the total intensity of th
$R + O + Y + G + B + I + V$; also let r, o, y, &c., be the fractio

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bsorption, a unit of thickness of the medium; then the rom a layer whose thickness is e, will be

$$Oo^e Y + y^e + Gg^e + Bb^e + Ii^e + Vv^e.$$

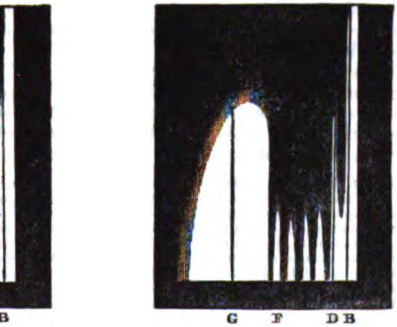
n containing the smallest of the fractions r, o, y, &c., reases; the colours corresponding to the other terms re and more, and the emergent tint will not be white, nt depending on the relative magnitude of the several ys of any one colour, red for example, are less absorbed ble, by increasing the thickness of the film, to a certain nsibly homogeneous; for by increasing e, the ratios be increased in any required proportion. When, on the &c., differ but little from unity, and the thickness of $Rr^e + Oo^e$ + &c., differs but little from that which repre- dent ray; that is to say, the light is not perceptibly

e several coloured rays absorbed by a coloured medium served by viewing a line of light through a prism and ectrum will then be seen to be diminished in brightness off altogether in others. This mode of observation is analysis, as many coloured substances when thus ex- tic spectra, the peculiarities of which may often be solution of the substance under examination contains impurities to change its colour very considerably. The he observation is given by Professor Stokes (Chem.

en of dense flint glass, ground to an angle of 60°, and eye comfortably. The top and bottom should be flat, prism between the thumb and fore-finger, and laying to scratch or soil the faces. A fine line of light is slit in a board 6 inches square, or a little longer in a ting to the aperture two pieces of thin metal. One of allow of altering the breadth of the slit. About the breadth for ordinary purposes. The board and metal l.

's length against the sky or a luminous flame, the slit ertical direction, and viewing the line of light thus close to the eye, with its edge vertical, a pure spectrum of the prism. Turning the prism round its axis alters is is got by trial. The whole of the spectrum is not, e, so that, in scrutinising one part after another, it is ttle. When daylight is used, the spectrum is known to ncipal fixed lines; in other cases the focus is got by the he other objects, whatever they may be, which are pre- bserve the absorption-spectrum of a liquid, an elastic near the top, and a test-tube containing the liquid is holds it in its place behind the slit. The spectrum is e test-tube being turned from the eye.

Fig. 669.



ss of the absorption, different degrees of strength must ng with a strength which does not render any part of

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the spectrum absolutely black, unless it be one or more very na
wise the most distinctive features of the absorption might be mi
be contained in a wedge-shaped vessel instead of a test-tube
absorption may be watched in a continuous manner by sliding
eye. Some observers prefer using a wedge-shaped vessel in com
the slit being perpendicular to the edge of the wedge. In this
the slit forms an elementary spectrum corresponding to a thi
which increases in a continuous manner from the edge of the we
This is the mode of observation adopted by Gladstone. (Che

Fig. 668 represents the effect produced in this way by a solu
of chromium, and *fig.* 669 that produced by a solution of perma
The right hand sides of these figures correspond with the red
the letters refer to Frauenhofer's lines. The lower part of each
spectrum seen through the thinnest part of the wedge, and the p
tion, as the thickness of the liquid increases, is seen by the grad
spectrum towards the upper part of the figures.

The following observations on the application of the absorptio
analysis, are extracted from a paper by Professor Stokes (Chem

"In many cases nothing is observed, beyond a general abso
end of the spectrum, or of its middle part, and the prism gi
beyond what is obtained by the eye, by observing the *succession*
by different thicknesses of the liquid. And here it may be rem
reference to the description of pure substances, that in specifying
corresponding to a considerable thickness, as is commonly d
peculiar features of the absorption are left almost wholly undes
solutions, one might be pink when dilute, passing on to red with
and thickness, another yellow, passing through orange to red
monly be described as red, yet the series of tints indicates an
mode of absorption, the middle of the spectrum in the one case,
gible end in the other, being the most powerfully attacked.

"But in some cases, especially with substances of intense colo
of absorption is eminently characteristic. Two or more dark
spectrum, indicating maxima of absorption; and the positions
relative intensity, and their other features, form altogether a s
distinctive nature of which is such as those who have neglected
have little conception of. They render it perfectly easy in ma
particular substance among a host of impurities. For each co
duces its own absorption, independently of the others (supposi
not chemically react on each other), so that, unless the part of t
the distinctive bands, or most of them, occur, is wholly absorb
the presence of the substance can still be recognised. Such a co
the less likely to occur, for this reason, that when the characters
strongly marked, it almost always happens that a comparatively
substance suffices to produce the effect, and the solution mus
much diluted that the effect of the impurities comparatively dis

"Nor is this all. When a substance exhibits marked charact
solvent, it often happens that it shows different and no less m
solvent of a different nature. Not only does this furnish adc
which the substance can be distinguished from others, but it is
the substance when involved in impurities: for the nature of t
such as to mask the substance in one solvent and not in anoth
the case where one solvent is alkaline and the other acid; but
times observed even with two neutral solvents.

"To illustrate these principles, we may refer to the colourin
Alizarin and purpurin both yield highly distinctive spectra, the
in the case of solutions containing caustic alkali,* whereas most
are highly distinctive. Madder itself contains, either directly
composition, a number of substances which, in alkaline solutio

* A solution of alizarin in carbonate of potassium or sodium, or in amm
having a band of absorption in the yellow, another narrower one between the
third very inconspicuous band coinciding with the line E.—Purpurin, disso
sium or sodium, exhibits two dark bands of absorption about the green part of
of the same substance in aqueous alum exhibits the same peculiar mode of
yellow fluorescence.—A solution of purpurin in sulphide of carbon exhibits f
which the first, situated in the yellow just beyond D, reckoning from the
than the rest; the second is situated in the green, nearly coinciding with the li
[illegible] which is very inconspicuous, in the indigo.—Lastly,
[illegible] exhibiting two bands of absorption; one narrow an
[illegible] E; the second in the blue, broader and less strong
[illegible] he solution is also slightly fluorescent. (Stokes, Che

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nctive bands of purpurin occur. Hence, in a mixture
ntaining, we will suppose, purpurin in comparatively
purpurin would, *in an alkaline solution*, be masked by
ther or acidulated alcohol the other substances yield
ular, and interfering comparatively little with the dis-
le in an alum-liquor solution made by boiling, not only
n this solvent occur at a lower refrangibility than with
ted from the absorption produced by the associated
s themselves are also in good measure excluded.
ssity of attending to the nature of the solvent, even in
vents, we may refer to a yellow substance which is one
colouring matter of leaves. The alcoholic solution of
aracteristic bands of absorption, the first of which is
o the line F on the more refrangible side. The solution
two similar bands, but much less refrangible, the line
ht interval between the first and second dark bands.
composed by acids, and even by acid salts, yielding a
, in alcoholic solution, exhibits two bands of absorption,
good deal more refrangible. There is the same change
, in passing from alcohol to sulphide of carbon, so that
f decomposition in sulphide of carbon agrees almost
, with that of the parent substance in alcohol.
of the absorption-spectrum of a substance useful for
nce through mixed solutions, but it sometimes reveals
they might not be suspected, if the origin of the sub-
the purpureïn of Dr. Stenhouse dissolves in ether or
olour, while that of the same solutions of purpurin is
, in both cases alike, the existence of three bands of
while the purpureïn bands are situated nearer the red
t one interval. This example shows how deeply seated
a body may in some cases be the cause which produces

sed that the peculiarities of absorption of a substance
e detection of that substance in a mixture. But the
nixture of an unknown number of unknown substances,
liarities of absorption, to determine whether the whole
the same substance, and, if not, what portion are due
ion to another. Little can be done towards the solution
bservation of absorption; we can only say, that some
absorption are common in solutions of pure substances,
d give rise to the suspicion of a mixture. The pheno-
me cases material assistance; but in general it is only
is with processes of chemical separation, especially
sfactory conclusion can be arrived at. When a mixture
a conviction, at last approaching certainty, is gradually
absorption which are always found accompanying one
ame substance.
ty of manipulation, especially in the examination of very
nethod of separation equal to that of partition between
agitation. Ether combined with water, either pure or
the most generally useful, and the separation, if not
ndered so by introducing the acid or alkali by minute
r solvents are useful in particular cases. Sulphide of
lcohol affords the means of disentangling the coloured
ether in the green colouring matter of leaves. Solutions
ich are naturally precipitable by an alkali or alkaline
solution by means of a tartrate, are very useful in the
ing matters, not merely for producing changes of colour
ation, but even, in conjunction with ether, for effecting
ional separation may be effected by making the solution
ect neutrality. By combining with ether such a solution
ible to separate and detect the purpurin, alizarin, and
f powder not exceeding in bulk a fraction of the head of

on the absorption spectra of metallic salts are by Dr.
79):
ra exhibited by different salts, only one constituent of

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which is coloured, shows that, with very few exceptions, all t
base or acid have the same effect on the rays of light. Thi
in many instances which at first sight appear exceptional. T
some salts of chromic oxide are green, others red or purpl
coloured chromic salts all exhibit the same general form of spe
the violet and indigo rays are very soon cut off; and as th
light is more and more concentrated about two points—on
the bluish-green, the red ray penetrating with the greatest
the chloride and other salts of chromium, which are gr
solutions, appear purple or red when we look through a str
The acetate absorbs the green rays more readily, and theref
very weak solutions, or in thin strata, while the "red potas
green so speedily that the thinnest portion of it appears bluis

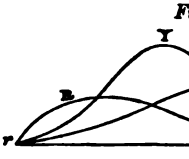
Salts composed of a coloured base and a coloured acid exh
of the rays which are not absorbed by either, the resultant
instances, but little resemblance to the original colours. T
chromic oxide, a compound of two substances which give
green solutions, is not bright green, but brownish-red, becau
off nearly all the blue and violet rays, while the oxide of chr
and the greater part of the green.

Some salts which are but slightly coloured, nevertheless e
spectra. Thus, a solution of sulphate of didymium, which h
exhibits, when examined by the hollow wedge and prism, a
very black lines; one in the yellow, the other in the green.
very weak solutions of didymium, and therefore serve as a de
they, moreover, afford means of distinguishing it from ceriu
spectra of which they do not occur.

Brewster's Theory of the Spectrum. Newton regarded the
an infinite number of simple colours, each element of it consi
refrangibility and not capable of further decomposition; and t
universally received as affording satisfactory explanations
colour, and of the decomposition and recomposition of ligh
studying the decomposition of light by absorption, observe
regarded as incompatible with Newton's theory, and he acc
theory of the constitution of the spectrum, which is as follow

1. White light is composed of *three* colours only, red, yel
certain proportions.

2. The solar spectrum is formed of three superposed spectr
them extending the entire length of the spectrum, but with va
in *fig.* 670; where the horizontal line *rv*, represents the length
three curves, R, Y, and B, are so drawn that their ordinate
intensities of the several colours at each point, the blue ha
the fixed lines F and G, the yellow near F, and the red, two
another of lower intensity near the
violet end of the spectrum.



3. All the colours of the spectrum are compound, and as all the rays united in one point have the same degree of refrangibility, they cannot be further decomposed by refraction.

Brewster was led to these conclusions by observing that when the spectrum is viewed through certain coloured media, white light may be s
of it. Thus, by looking through an azure-blue glass of suffi
through a solution of sulphate of copper mixed with red ink, th
replaced by white, very slightly tinged with green or red, ac
tint of the medium. This white light is not decomposible
decomposed by viewing it through a film of gelatin of ye
white band then appearing yellow or green, in consequence
blue or red rays. By similar means Brewster found white li
orange, whence he concluded that the three primary colours e
and orange of the spectrum. In like manner, by viewing the
yellow liquids, he found that the blue and indigo assumed
concluded that red light exists in these parts of the spectrum
trum seen through a film of blue gelatin, exhibited a white
indigo viewed through a blue glass assumed a violet tint: hen

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ewing the spectrum through a layer of Peruvian balsam,
mica, yellow was seen in the red near the line C.
t yellow in the violet, but he attributed this negative
ght in this part of the spectrum, and the facility with
loured media. Lastly, the red of the spectrum seen
sulphur-balsam, or red mica, appeared green, whence it
spectrum also contained blue.
ever met with general adoption. In the first place, it is
-theory of light: for just as there is an infinite number
infinity of wave-lengths in the air, so likewise must there
s of colour corresponding with an infinite number of
herefore also (p. 609), an infinite number of different
nand, to account for the dark lines of the solar spec-
uppose that certain rays are wanting in the component
ts, which is very improbable.
whatever for assuming that red, yellow, and blue are the
ht; indeed, Helmholtz has shown, by a method to be
ual colours of the spectrum may be more exactly imi-
een, and violet, but that even then the imitation is far

Airy, Helmholtz, and others have likewise shown that
orne out, even by his own method of observation, when
eliminate sources of error. Airy has pointed out that
h a mode of experimenting, it is necessary in the first
ght, which, being decomposed by the coloured medium,
nd, secondly, to compare the spectrum viewed through
re spectrum viewed directly, the two being formed
, as in no other way can an exact comparison of the
of the two be made. When these precautions were
to distinguish the slightest difference, excepting in
f the spectrum seen through a coloured medium, and
rectly. Airy also observes that the intensity of the
ence in the impression produced on the eye by any

e results may be modified by the light scattered by
of the coloured medium, and by the lens and prism used
when the absorbent medium used is a film of gelatin,
To eliminate this diffused light, the spectrum is received
through which a thin coloured pencil can pass, and
on a second prism, followed by a lens, which forms a
a faint spectrum proceeding from the diffused light
econd aperture. This spectrum does not perceptibly
e. On examining the different colours of this purified
ed media, it was found impossible to distinguish any
lours thus observed and those viewed directly.
may be inferred that it is impossible to decompose the
ption any more than by refraction; that the colours, as
d that to each colour there corresponds a definite de-

tion of Light by Reflection.

s of bodies by supposing that they decompose the
, absorbing some of the component rays, reflecting
they are opaque, or reflecting one portion and trans-
ansparent, the reflected and transmitted light being
ecause the different coloured rays are not absorbed
k substances are those which absorb all the rays
bstances, those which reflect all the rays; bodies of
e manner on all kinds of luminous rays. But between
nfinity of substances which reflect the several coloured
A red body, for example, is one which reflects red in
rays composing white light. In the case of opaque
light takes place at an insensible depth below the sur-
nt of the inner layers of the substance.
prism be thrown on a *white* surface, each point reflects
appears of the same colour as that light. If the surface

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is *red*, it appears very bright in the red part of the spectrum, but th faint, the red surface reflecting the red rays of the spectrum abund colours in small proportions only. If the body is capable of abs completely, black bands are seen in the corresponding parts of the s body be illuminated solely by rays of that particular degree of refra black.

A coloured body illuminated by different sources of light m colours, the spectra formed by the light from these several sources the same colours or in the same proportions. It is thus that objects daylight appear blue by lamp-light, the yellow rays being less abu ordinary flames than in solar light. Most objects appear diff moonlight, from what they do by daylight. When a series of t colours of the spectrum is illuminated by the monochromatic ye fed with spirit containing common salt, the yellow, orange and red s of various degrees of brightness, the rest grey or black, because rays which they are capable of reflecting, or in other words, becaus not susceptible of vibrating in unison with those of the light whi In the same light, the face and lips appear of a livid hue, because the skin reflects in daylight are wanting in the yellow light.

When the body on which the light falls is transparent, the rays it are those which have not been reflected at its surface; henc transmitted light may be of different colours. Such is in fact th stances. Gold-leaf, which is yellow by reflected light, transmits ligh colour. Faraday formed pulverulent deposits by sending powerful through metallic wires in an atmosphere of hydrogen: in the finely produced, copper appeared green by transmitted light; tin, brow bluish-grey; palladium, brown; aluminium, brown or orange-colour and transmitted rays are sometimes complementary to each other; only when no part of the light is absorbed. When a body exhibi red for example, both by reflection and by transmission, it is bec of the red rays of the incident light, transmits the rest, and absorbs other colours.

In many cases, however, as pointed out by Professor Stokes (315), the colour of a body attributed on cursory examination to refl to transmission; in fact, the instances in which substances appear tion are comparatively rare. "A chemist views a solution containe transmission and then by reflection; and seeing perhaps some colour in the latter case, describes it as the colour of the solu whereas it is merely the colour by transmission due to a greater having been reflected at the back or bottom of the test-tube, an passed through the solution. In other cases, the colour described really arises from fluorescence; and though the statement may be intended, it seems objectionable to apply the term *reflection* to a different. It is only in the case of metals, such as gold and cop other substances, such as murexide, platinocyanide of magnesium, really seen as the result of reflection.

"When this takes place in the case of non-metallic substances, th endowed, for the colours so reflected, with an intense opacity, comp metals; while for other parts of the spectrum, they may be compara and these parts they reflect with an energy comparable to that of a only. The variations of absorbing power in passing from one part another, and consequently the variations in reflecting energy, are more considerable, and accordingly the colour by reflection is much case of metals."

"An excellent example of the intimate connection between met intense absorption is afforded by the crystals of permanganate of crystals exhibit a green metallic reflection, and when crushed yie intense purple colour by transmitted light. The colour is too i analysis, but the solution has a similar colour, merely less intense a its smaller concentration, and the analysis of the light transmitt presents no difficulty. The green is quickly absorbed, but when th ciently dilute, five eminently characteristic bands of absorption are of the spectrum. A sixth band comes out with a greater thickness solution, but even the fifth is somewhat less strong than the others. reflected from a crystal is analysed, four bright bands are seen stand rally luminous ground of inferior brightness. These bright bands tion with the principal *dark* bands in the light transmitted by

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y the crystals themselves. When the angle of inci-
he reflected light is analysed by a Nichol's prism, with
e of incidence, and then by a common prism, the
bright bands. A fifth bright band could, perhaps,
ne crystal with a fresh surface. Under the circum-
sm would extinguish the light reflected from a vitreous
that reflected from a metal. We see, therefore, that
he crystallised body passes repeatedly from the con
etallic substance and back again, as the refrangibility
it is considered, is continuously increased by a small

ntense absorption and metallic reflection exists gene-
studied by means of a solution. The platinocyanides,
utions, so that the intense absorption which most of
the spectrum must be attributed to the mode in which
ming the crystals; but by attending to the colour of
ystals, the law is found to be obeyed. Gold can only
d by means of the opaque solvent mercury; but its
udied in gold-leaf, or in a chemically deposited film,
ble to the law mentioned, the less refrangible colours,
ore copiously reflected, being also those which are the

the property of coloured reflection, such as permanen-
in consequence of the necessary dilution, the opacity
ny part of the spectrum, of that intense kind which is
ection; and accordingly the light reflected by the

to reflection should appear, it is necessary that the
amount of coherence. Thus indigo in the form of a
when viewed by reflection. It would be erroneous,
blue by reflection, if we were speaking of the pro-
the mere crude results of observation made under
h it is true that the light by which the blue colour is
thout which it would not have reached the eye) it is
tic selection is made by virtue of which the powder
ission. In fact it is only a small portion of the light
gular surface of the mass; the greater part penetrates
arious depths, and in passing through the particles, in
orption on the part of the coloured substance. Were
for *all* the colours of the spectrum, the powder would
in the case of platinum-black. By burnishing, the
of a somewhat coherent mass, and it now begins to
reflection. The internal reflections are at the same
he part of the light which is reflected from beneath
uch reduced. A pressed mass is not, however, an
, so that the colour by reflection obtained by bur-
ite pure. In the state of a fine crystalline powder,
copper colour due to reflection, and the blue colour
rved in the light reflected from the mass as a whole;
e obtained in large crystals, the colour by reflection
nd the colour by transmission would disappear, the
(Stokes.)

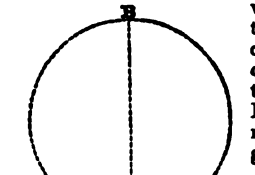
Colours of Thin Plates.

hen reduced to very thin films, exhibit brilliant colours
iar instance of this; glass blown out into thin films
, likewise, does a layer of oil spread over the surface
er, are best studied in the case of a thin film of air
ass. When two glass plates (of any sort of glass) are
spot is observed at the point of closest contact, and
ibiting remarkably beautiful colours: if the light be
flame, the bands are alternately light and dark. The
on the greater or lesser regularity of thickness in the
pressed at one point that the intervening space shall
he bands will be circular—otherwise they will have an

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irregular shape—but in all cases the same thickness of the f
paribus, the same colour. Newton, to whom this experimen
plano-convex lens of small curva
of flat glass: by this means he
whose thickness was uniform at
the point of contact, and the fri
circular. By this arrangement als
of the lens, he was enabled to ca
the film of air by which any partic
For, the radius of the ring AM (
measurement, and the diameter o
given, we have AB × AN (or MP)

Fig. 671.



therefore MP = $\frac{A}{A}$

whence also MP varies as AM².

Proceeding in this manner, Newton found that the thickness
which the successive dark bands were formed varied in the ra

0, 2, 4, 6, ... $2n$;

and those by which the light bands were produced in the num

1, 3, 5, 7, ... $2n+1$;

further, that the thickness of the film at the first bright band
inch for red light, and about $4\frac{1}{4}$-millionths for violet light.

Now comparing these numbers with those afterwards found b
of the waves (p. 600), it is found that the thickness of the film
length of a wave.

The explanation of this phenomenon is as follows:—The ban
terference of rays reflected from the upper and under surfaces
Now at the centre, where the two surfaces are in almost abs
expect the reflected rays to be in acordance—for they reach
over equal paths. At the first bright band, the thickness = $\frac{1}{4}$
the ray reflected from the second surface, which has to travers
behind the other by half an undulation, and might therefore be
other: but instead of that, the two assist each other and produ
larly with the other bright bands, which are produced by ray
length by

$\frac{3}{2}, \frac{5}{2}, \frac{7}{2}$ . . . . $\frac{2n+1}{2}$ of a wave-l

The dark bands are formed by rays which differ by

0, $\frac{2}{2}, \frac{4}{2}, \frac{6}{2}$ . . . . $\frac{2n}{2}$ of a wave-l

and which might therefore be expected to be in accordance.

The explanation of this apparent anomaly is found, as point
manner in which the direction of the vibrations of the ether-
passing from one medium to another.

When a wave of light travels through a medium of uniform
returns upon its path; no reflection takes place, but each part
state of vibration, communicates its vibration to the next, and
just as an ivory ball striking upon another of equal size, drive
is itself brought to rest. But if the vibration is communicat
ferent constitution—as when a ray passes from air into glass,
this complete destruction of the vibration of the particles does
consequence is, that the light is at the same time transmit
medium, and reflected back into the first. If the ray passes
the ether is of greater density to one in which it is of less
into air, the direction of vibration of the particles in the re
changed, just as a large billiard ball striking a small one, dri
it, and continues in its own course though with less velocity.
when the ray passes from air to glass, that is to say, from
ether of greater density, the vibration of the particles in t
versed—just as when a small ball strikes a large one, the larg
but the small one driven back upon its path.

To apply this to the case of Newton's rings. The bands a
ference of rays reflected from the first surface with rays ref

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w in the second reflection, according to the principle the particles of the reflected ray is reversed, because ss, whereas at the first surface, where the ray passes ersal takes place. Consequently the two rays, when ations in accordance, just when they would have been f vibration at the second surface had not taken place. luced where the thickness of the film is

$$2d,\ 4d,\ 6d\ \ .\ .\ .\ \ 2nd,$$

e thickness is

$$3d,\ 5d,\ 7d\ \ .\ .\ .\ \ (2n+1)\,d$$

nation of the phenomenon is proved by the fact that substance is placed between two other media, one of fracting power than itself, the positions of the light and when a film of oil of sassafras is placed between a plate ass, the central spot is *white*; and the thicknesses of the l numbers for the dark, and of the even numbers for the

se of a film of air between glass plates. Fringes are ell as by reflected light, but the colours of any particular y of those of the same ring formed by reflected light; us, the central spot is light, and the bands follow the ey do when formed by reflected light. These transmis- interference of rays transmitted through the film, with it after having undergone two reflections, one at the t the first; and since both these reflections are made in hange of direction caused by the first reflection is again onsequently the rays are in accordance or discordance, n in case of no reflection at all.

of Refraction and the Thicknesses of the Films.—The different substances, at the points where they form rder, are to one another *in the inverse ratio of their*

bright fringe of the mth order. If λ, λ' are the wave- ght in the two substances, and e, e' their thicknesses, we

$$2m + 1)\tfrac{1}{4}\lambda;\ e' = (2m + 1)\tfrac{1}{4}\lambda';$$

μ.

by experiment. It may be verified for air and water between the two glass plates which produce the rings, ween the plates by capillarity, and expelling the air from nd the point of contact. It will then be observed that es with the fifth ring in water. Now the thicknesses of t rings in air are, e, $3e$, $5e$, $7e$, $9e$, &c., and in water e', ult just described gives, therefore, $7e = 9e'$; whence

x of refraction of water referred to air as unity.

onal method of measuring the indices of refraction of r in the expression $e : e' = \mu' : \mu$, the ratio of the thick- t of the squares of the diameters of the rings of the same dex of the liquid may be calculated as a function of that owever very exact, in consequence of the difficulty of e rings.

hat the eye is placed directly over the centre of the rings, pendicular incidence. If the eye be moved from this gs obliquely, these diameters increase as the incident rays ; that is to say, the thickness of the transparent film en order increases with the obliquity of the rays; in other rings follow the same laws as when the incidence is per- experiment, that the thickness e, of a ring of given order ce, is connected with the thickness e, for the same ring pposing the thin film to be formed of the same substance nds the apparatus—by the equation, $e = e' \cos i$, or $e' =$

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The diameters of the rings, like the breadths of all oth
greatest in red, and least in violet light; hence in white ligh
is produced not separated by any absolutely dark spaces.

The following table exhibits the succession of colours prod
and the corresponding thicknesses of three different media:

Newton's *Table of the Colours of Thin Plates in Air,*

Succession of *Spectra* or *Orders* of Colours.	Colours produced at the thicknesses in th last three columns.	
	Reflected.	Transmitted.
First Spectrum or Order of Colours	Very black Black Beginning of black Blue White Yellow Orange Red	White Yellowish-red Black Violet Blue
Second Spectrum or Order of Colours	Violet Indigo Blue Green Yellow Orange Bright red Scarlet	White Yellow Red Violet Blue
Third Spectrum or Order of Colours	Purple Indigo Blue Green Yellow Red Bluish-red	Green Yellow Red Bluish-green
Fourth Spectrum or Order of Colours	Bluish-green Green Yellowish-green Red	Red Bluish-green
Fifth Spectrum or Order of Colours	Greenish-blue Red	Red
Sixth Spectrum or Order of Colours	Greenish-blue Red	
Seventh Spectrum or Order of Colours	Greenish-blue Reddish-white	

Beyond these limits, the colours become mixed to such
white light. If, however, the rings be viewed through a p
different coloured rays, a much larger number of them will

The transmitted rings are much fainter than the reflected
beams of light which contribute to their formation has been
reflection is attended with a considerable loss of light.

We have been particular in describing the colours of 'Ne
are generally used as a standard of comparison for all colou
upon interference.

Colours of Thick Plates.—This term is applied to certa
or fringes, produced by interference at the surfaces of tran
exhibit the peculiar phenomena known as the colours of th

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of silvered glass a thin beam of solar light passing into
all aperture situated at the centre of curvature of the
aperture a series of coloured rings having the violet
ours of thin plates. With homogeneous light, the rings
dark. Newton found by measurement—1. That the
egulated by the same laws as those of the rings formed by
2. When different kinds of homogeneous light are em-
eters are the same as in thin plates. 3. The diameters of
f equal radius and different thickness, are inversely as
esses.

gs depends, however, on a condition which Newton did
er surface of the mirror must not be quite bright. If
and carefully cleansed, the rings are scarcely visible;
le dull by breathing or throwing dust upon it, or by
varnish, or of water whitened with a little milk, which is
e out with great brightness. If, on the other hand, the
back of the mirror, the rings become very faint, and
t all are produced. These experiments show that the
erference of rays reflected from the second surface of the
reflected from the first surface, which has been dulled.
t by an experiment of the Duc de Chaulnes, who, instead
llic mirror, before which he placed a piece of plate glass
arnished, or a plate of mica, either of which fulfilled the
urface of the glass mirror.

arent plate, places in front of the mirror a screen pierced
whatever, but small enough to cause both the incident
he mirror to come in contact with its edges. A straight-
f the mirror, is even sufficient to produce the rings; but
circumference is seen.

d light may be viewed directly without being projected
candle in the centre of curvature of the mirror with
mage of the candle may coincide with it, and places the
he centre; beautiful rings are then seen formed in the
near the eye, at about a yard from a plane mirror with
andle and its image may seem to coincide; he thus ob-
s round the image of the candle. Herschel receives a
e spherical metallic mirror, and intercepts the reflected
rming a cloud of dust in the air in front of the mirror,
siderable brightness.

in which coloured rings and fringes may be formed by
r, for the description of these and for the more detailed
to works specially devoted to light. (See Daguin,

omposition of Colours.

compound. The simple colours are those of a pure
fraction through a prism, or by diffraction through a
colours are produced by the mixture of two or more of
instance of Newton's rings, or the fringes produced by
s may be similar to the pure colours of the spectrum,
em in the impression which they produce on the visual
roduced by the mixture or superposition of any number
tigated by one of the following methods:
ances in fine powder. This method, however, yields
, in consequence of the large quantity of light absorbed;
m the surfaces of the two substances are mixed with
a certain depth, and have been there reflected, so that
ced by the mixture of the rays directly reflected from
rs arising from absorption.
aper certain portions of a revolving disc, tinted with the
), the colour perceived being that which is produced by
g spectral colours.
paper with the colours whose composition is to be
k table, setting up between them a plate of unsilvered
hat the image of one of them seen by reflection may
her seen directly through the glass (Helmholtz).

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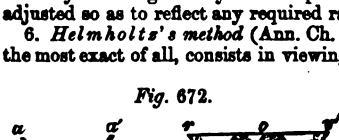
This and the second method are preferable to the first, the or
ing them being the deviation of the artificial colours from the p
The only way of attaining perfectly accurate results is to ope
of the spectrum itself, as in the following methods:

4. By intercepting some of the coloured rays as they eme
bringing the rest to a focus by an achromatic lens.

5. By receiving the rays of the spectrum on a row of plane
adjusted so as to reflect any required rays to the same point o

6. *Helmholtz's method* (Ann. Ch. Phys. [3] xxxvi. 500).
the most exact of all, consists in viewing, through a vertical pri
a'b, forming a right ang

Fig. 672.



clined 45° to the edge
being placed about fo
and in the position
spectra *r v*, *r' v'*, are s
aid of a telescope, the
be distinguished parall
spectra are partly superp
of the slits must be such that each coloured band *o o* of one
the coloured bands of the other.

To find the effect produced by the combination of two
directed so that the intersection of its cross-wires is projected
be examined, and the eye is placed behind a small hole in a s
metres from the telescope, so that it may perceive only a very
point of intersection. The compound tint required may thu
being affected by the neighbouring colours. By then covering
sively, the simple colours which have produced the combinatio

In order to vary the relative quantities of light in the comp
was inclined in such a manner as to bring it more nearly paral
The spectrum of this slit was thereby brought nearer to the r
colours were more condensed, while the contrary effect was p
the other. By adding a third slit, the effect of combining
observed. By these means Helmholtz has obtained the follow

1. The compound tint formed by the mixture of two simp
identical with a simple colour of the spectrum, but in many c
them all: for example, the greenish-yellow and greenish-blue
green much darker than that of the spectrum. This last gree
and red of the spectrum, cannot be imitated exactly by th
colours. 2. The colour produced by the union of three sim
from that which would be obtained by combining one of them
the spectrum, similar to that which results from the combina
For instance, the red and bluish-green of the spectrum form *y*
bluish-green produced by the union of green and indigo, form
many combinations of three colours which form white. 4. W
is not possible to obtain satisfactory imitations of all the colou
number of simple colours required for the purpose being at lea
green, *blue*, and *violet*. Hence, according to Helmholtz, the t
colours (p. 640) does not rest on a satisfactory foundation; a
obtain something like an imitation of all the spectral colours b
coloured powders, the result must be attributed partly to the
the colours used, partly to the circumstance that the resulting
not generally been directly compared with the colours of the s
most instances, they differ considerably. The three colours hi
blue, and *yellow*, are not even the three best adapted to the pur
obtained with red, green, and violet, but even then the imitatio
For the contrary results obtained by Maxwell, from which it
whatever may be produced by the combination of three primar

Complementary colours.—This name was applied by Newt
which by their mixture produce white light; such are *green* and
yellow and *violet*.

Every colour, whether simple or compound, has its compleme
every colour has an infinity of complementary colours, inasmu
colours be mixed with white in any proportion, the two will st
union.

Helmholtz has made some remarkable experiments on co
throwing the pure spectrum, formed by a prism and achron
pierced with two narrow slits parallel to the edges of the pris

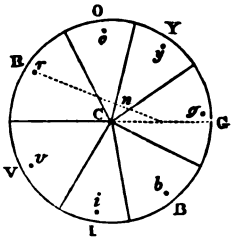
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re. The two homogeneous coloured pencils thus
nich condenses and brings them to a single focus on
le distance. By this mode of experimenting, Helm-
an infinity of binary groups of colours, which, when
a perfect white. With the exception of pure green,
m is complementary of another simple colour.
ne of the slits, the relative intensities of the two
and it was thus found that the proportions between
ams which produce white light by their combination,
y of the incident light. This is shown by the follow-

olours.	Ratio of intensity of the second colour to the first.	
	Bright light.	Faint light.
llow . . .	10	5
. . . .	4	3
. . . .	1	1
. . . .	0·44	0·44

g led to the unexpected conclusion that the mixture
spectrum produces white, whereas the mixture of
always produces green. This result is confirmed by
chromate of lead or gamboge, the other with cobalt-
e of the one coincide with
e other, as in method 3
nus seen is white. With
l artificial ultramarine,
ge; with Prussian-blue,
of green by the mixture
uids, arises from partial
orption, as explained at

Fig. 673.



alculation of composite
rical construction was
approximately the result
colours. The circum-
vided into seven parts corresponding with the seven
and proportional to the numbers $\frac{1}{5}$, $\frac{1}{16}$, $\frac{1}{10}$, $\frac{1}{9}$, $\frac{1}{10}$, $\frac{1}{16}$, $\frac{1}{5}$.
the following lengths of the arcs belonging to the

5′	34″	Blue	. . .	54°	41′	3″
0	38	Indigo	. . .	34	10	38
1	1	Violet	. . .	60	45	34
5	3					

f these arcs *r*, *o*, *y*, *g*, *b*, *i*, *v*, are then marked; and
xture of several colours, forces proportional to the
ixed are supposed to be applied to the centres of
and the point of application of the resultant of these
sought will be that of the arc of the sector in which
Thus, to find the result of mixing red, blue, and
to one another as the numbers n_r, n_b, n_y, we must
ne resultant of three parallel forces proportional to
ts *r*, *b*, *y*. If this point falls at *n*, the mixture will
use the point *n* is nearer to the limit of the green
nearer the point *n* is to the centre C, the more will
h white; if it coincides exactly with C, the mixture
en the seven colours are combined in quantities pro-
sent them, the resultant being then applied at the
rcumference.

1. That two simple colours following one another on
r mixture an intermediate tint; an exception must
red and violet, which do not follow one another in
parated by a third, yield that third by their mixture;
, orange and green yield yellow, &c. Indigo and
posite extremities of the spectrum, yield a reddish

ethod to a general formula. For this purpose he

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calculates the co-ordinates of the centres of gravity of the
abscissæ the straight line passing through the point of se
sponding to the violet and red, and through the centre, t
ordinates; he then multiples each co-ordinate by the numbe
ing colour which is to enter into the compound, divides the
sum of the rays which are to be compounded, and thus obt
point of application of the resultant. Designating the num
by the initial letter of its name, these co-ordinates are:

$$X = \frac{0{\cdot}82284\,(r+v) + 0{\cdot}207398\,(o+i) - 0{\cdot}513992\,(}{r+o+y+g+b+i+v.}$$

$$Y = \frac{0{\cdot}48235\,(r-v) + 0{\cdot}963163\,(o-i) + 0{\cdot}81}{r+o+y+g+b+i+v.}$$

These co-ordinates give the distance D, of the point of i
from the centre of the circle, as well as the angle α, wh
points makes with the axis of x: for $\tan \alpha = Y : X$; and Y

The value of α shows in which particular sector the point
ratio D : 1 − D shows the proportion of simple light and
resulting colour.

The preceding method was given by Newton as an em
the results which he obtained by forming compound colours c
of simple light at the focus of a lens. It cannot be rega
approximation, and is, indeed, less exact than Newton su
example, that the mixture of blue and yellow rays may prod

A more satisfactory method of calculating the compositio
by Maxwell (Phil. Mag. [4] xiv. 40; Proc. Roy. Soc. x.
tions it appears that the colours of the spectrum, as laid d
method from actual observation, lie, not in the circumfer
periphery of a triangle, showing that all the colours of the
cally represented by three, which form the angles of the t
and positions in the spectrum of these three primary colour

Wave-lengths in millionths o

Scarlet	.	2328—about one-third from
Green	.	1914—about one-quarter fro
Blue	.	1717—about half-way from

This form of the diagram of colour, as perceived by the h
with Young's theory of *three primary sensations* of colour, w
proportions, when different kinds of light enter the eye. A
threefold character of colour, as perceived by us, is due, not
of light, but to the constitution of the visual apparatus, w
being affected in three different ways, the relative amoun
determined by the nature of the incident light. If we c
corresponding to the three primary sensations, each colour
of these sensations, then, since all other colours whatever
primary sensation, they must find their places in Newton's
of which the three primary colours form the angles.

If this theory be true, the complete diagram of all c
human eye, will have the form of a triangle. The colours c
rays of the spectrum must all lie within this triangle, and
mixtures of these, must lie within the line formed by the sp
colours correspond with the three primary sensations, they
of the triangle, and all the others will be within the triangl

The other colours of the spectrum, though excited by u
compound colours: because the light, though simple, has th
more colour-sensations in different proportions—as, for i
though not compounded of the blue rays and green rays,
pounded of those of blue and green.

The three colours found by experiment to form the three
Newton's diagram, *may* correspond with the three primary

A different geometrical representation of the relations
scribed:—Take any point not in the plane of Newton's d
this point as origin through the point representing a giv
produce it, so that the length of the line may be to the part
intensity of any given colour is to that of the corresp
diagram. In this way, any colour may be represented by a
whose direction indicates the quality of the colour, and

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f two colours is represented by the diagonal of the
es representing the colours.
rigin through the points of the diagram corresponding
s of co-ordinates, any colour may be expressed as the
of each of the three primaries, and the three elements
ed by three dimensions of space.
which the preceding conclusions are established con-
f the spectrum, and mixing them in such proportions
brightness with a constant white light. Three standard
quantity of each required to produce the given white
es of two of these, combined with a fourth colour which
e then determined. A relation is thus obtained between
urth colour, whence its position in Newton's diagram,
dards, may be laid down.
the experiment consists of a dark chamber about 5 feet
p, joined to another 2 feet long, at an angle of about
rrow slit at the end of the shorter chamber, falls on a
wo prisms in succession, so as to form a pure spectrum
Here there is placed an apparatus consisting of three
red in breadth and position, the position being read off
breadth ascertained by inserting a fine wedge into the

l at the shorter end, light of three different colours is
hen white light is admitted at the three slits, light of
n is seen by an eye placed at the slit in the shorter arm
ht employed is that of a sheet of white paper placed on a
un's light in the open air, the instrument being in a
here the observer sits.
white light goes down a separate compartment of the
surface of blackened glass, so as to be seen by the
th the compound light which enters the slits and is re-

ltering the breadth of the slits till the two lights seen
colour and in brightness. In this way the relative
were found by two observers, both of whom agreed in
ours to lie very close to the two sides of a triangle, the
forming doubtful fragments of the third side.
ween these sixteen colours being thus ascertained, the
tions of these colours with respect to Fraunhofer's lines.
into the shorter arm of the instrument through the
n the former experiments. A pure spectrum is then
position of the fixed lines is read off on the divided
he wave-lengths of each kind of light, the incident light
n of air too thick to exhibit the colours of Newton's
ibited a series of dark bands at intervals increasing
e wave-lengths corresponding with these form a series
ion; and by counting the bands between two of the
have been determined by Babinet (p. 607), the wave-
he bands may be calculated; and as there is a great
ths become known at a great many different points. In
the colours compared may be ascertained, and the
rendered comparable with those of another.
by Maxwell for comparing combinations of colour, is
inning-top, having its flat upper surface divided into
cle being further divided into sectors, which can be
papers. When the top is spun, the colours in each of
and the proportions of those in the outer circle are
es that produced by a given combination in the inner
asured by a graduation on the circumference.

.—The terms employed to designate different shades of
ry indefinite, being sometimes borrowed from natural
s from the names of inventors of preparations which
nd from various other sources more or less fanciful.
ally distinguished by comparison with familiar natural
s resemble: thus blues are specially distinguished as
ndigo- and sky-blue; greens as verdigris, celandine,
grass, asparagus, olive, oil, and siskin green; yellows

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as sulphur, straw, wax, honey, lemon, ochre, wine, cream, and ora
aurora or roseate, hyacinth, brick, scarlet, blood, flesh, carmine,
blossom, columbine, and cherry-red; browns as clove, hair, broc
and liver-brown; greys as pearl, smoke, and ash-grey.

To obtain greater accuracy in the nomenclature of colours, Che
following scheme (*De la loi du contraste simultané des couleur*
place he assigns definite meanings to the terms tint (*nuance*),
(*ton*), denoting by tint the result of mixing pure colours in variou
shade or tone the result of mixing any tint or simple colour w
that each tint is susceptible of an infinite gradation of shades.
lowered by the addition of white, strengthened or *heightened*
Colours mixed with black are said by painters to be deadened
reflect less light; in fact, if a coloured surface be less and less ill
continually darker and ultimately black. This effect is experi
day, all the colours then becoming darker and turning towards bl

Chevreul's Chromatic Circle.—Chevreul has formed a table o
dually one into the other, and each modified by 20 shades, some pro
white in various proportions, the rest by admixture of black. Imagi
72 equal sectors. Three equidistant sectors are coloured respecti
and *blue*, and at equal distances from these three colours are placed t
their mixture two by two, viz. *orange* between red and yellow,
and blue, *violet* between red and blue; then between these six ti
termediate tints, and so on till the whole 72 are complete. Eac
is then divided into quadrangular segments by 20 concentric ci
ments thus formed are placed the shades belonging to each colou
small white circle, starting from which each tint becomes gradual
tinual abstraction of white, till the pure tint is reached, and bey
continually deepened by addition of black till the circumference
quite black. There is therefore a circular series of segments con
with their maximum of intensity, and starting from these, the s
become weaker towards the centre, stronger towards the circumfe
colours contained in any one sector forms a gamut of shades of t
Each circle of segments contains the 72 tints corresponding wi
circle. We have thus a diagram of 1440 colours forming types
another for the requirements of the arts. It would be useful als
white, that is to say, the series of grey shades from white to bla
constructed with permanent colours, on painted porcelain for e
rendering important service in the arts, by affording a stan
colours, which may be designated by the numbers of the sector an
which they occur.

Lecocq arranges the coloured segments in a different way.
of a sphere into quadrangular spaces by means of meridians and
colours are placed at the equator, and each of them becomes dark
its meridian towards one pole, at which there is a black spot, an
other pole, where there is a white spot. It would be more conven
having one of its bases bordered with black, the other with white
arranged round a zone in the middle. The cylinder might al
plane, and the whole series of tints and shades thus presented to
repeating at one end of the diagram thus formed, some of the
posite end, each gamut will be placed next to those which dif
In this form the diagram is more easily constructed, especially
porcelain.

Polarisation and Double Refraction.

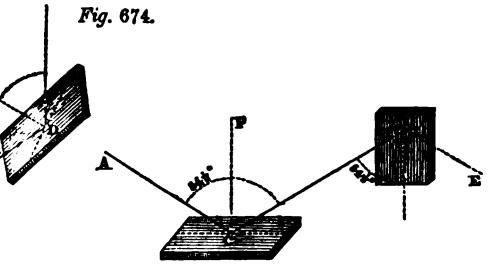
When a beam of light proceeding from a self-luminous sour
geneous medium without encountering any obstacle, it exhibits t
all sides,—on the north, south, east, and west, for example, if w
tical. The light composing such a beam is called *ordinary* or *nat*
the light has met with any obstacle, and has consequently un
refraction, it exhibits, for the most part, different properties on d
example, the beam of light be received obliquely on a glass mir
turned round it, taking care not to alter the angle of incidence
reflected beam will vary according to the side of it which is pre
A ray thus modified is said to be polarised. The properties
relate to changes of intensity or modifications of colour, and nev
in which they are reflected or refracted.

Light may be polarised in either of the following ways:—

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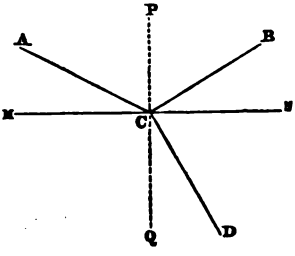
rface of transparent media.—Suppose a ray of light AC
f glass (not silvered, but blackened at the lower surface)

Fig. 674.



with the normal PC, or 35½° with the reflecting surface.
e direction CD, making an angle PCD = ACP, and in
Now suppose the reflected ray to fall upon a second
angle of 54½° with the normal. If, then, the second
ane of reflection is parallel to the plane of reflection from
figure), then the ray will be reflected from the second
st as if it proceeded directly from a luminous source, and
flection; but if the second mirror be so adjusted that its
ular to that of the first (see right-hand figure), then the
m it at all, or at least the intensity of the reflected beam
In intermediate positions, still at the same angle of inci-
ially reflected, the quantity of light in the reflected ray
of reflection of the two mirrors are more nearly parallel.
n glass at an angle of 54½°, appears then to exhibit dif-
the direction in which it is a second time reflected, being
egrees at different azimuths; it is therefore *polarised.*
sed ray is most easily reflected is called the plane of
ith the plane of reflection (or of incidence).
e polarising angle
there is a particular
de of which depends
he medium, according
ed by Brewster: *The*
) *is that for which the*
icular to the reflected
he index of refraction,
e angle ACP = BCP
endicular to CD, and
= 90° − θ; therefore,
to say, *the polarising*

Fig. 675.



t is equal to the index of refraction.
s the polarising angles of a few transparent substances,
rations of Biot and Arago:—

sing angle.		Name of substance.	Polarising angle.	
d	Measured from surface.		Measured from normal.	Measured from surface.
′	36° 10′	Topaz . . .	58° 40′	31° 20′
5	37 15	Iceland spar . .	58 23	31 37
5	35 25	Spinel ruby . .	*60 16	29 44
3	33 57	Zircon . . .	*63 08	26 52
3	33 32	Sulphur (native) .	*64 10	25 50
5	33 25	Antimony-glass .	*64 45	55 15
2	33 38	Chromate of lead .	*67 42	22 18
0	32 0	Diamond . . .	*68 02	21 58

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There are but few substances capable of completely polarising generally speaking the polarising power is least in those media indices of refraction. According to Brewster, it is only those index is less than 1·7, which are capable of polarising complete marked with an asterisk in the preceding table. But even whe 1·7, the polarisation is never complete, if the beam of light is bri stances which reflect but little light, polarise a large proportio clean and polished surface, polarise scarcely at all. In all case law applies to the incidence at which the reflected beam contain of polarised light.

As the several coloured rays have different indices of refra only homogeneous light can be completely polarised by reflection nary gas or candle light, can never be made to disappear con above described. In fact, with media of high dispersive powe diamond, chromate of lead, or specular iron, all the colours of successively brought into view by slightly altering the inclin surface in the vicinity of the polarising angle. With glass a angles of polarisation for the extreme rays of the spectrum do n 15′ or 20′, the colours are less perceptible; nevertheless the l entirely, and always exhibits a slight coloration after the second

Light is more or less polarised by reflection at all angles o perpendicular incidence, the proportion of polarised light in th greater as the angle of incidence differs less from the polarisin Brewster's law.

If a ray, partially polarised by reflection at any angle differi angle, be again reflected from the same medium at the same a polarised light in it will be increased; and by a number of suc ray may be brought indefinitely near to the state of complete po of reflections required for the purpose being less as the angle o from the polarising angle.

2. *By ordinary Refraction.*—When light passes from one med fracted ray is polarised as well as the reflected ray, its plane perpendicular to the plane of refraction, or of incidence, and plane of polarisation of the reflected ray. The refracted ray wil from a surface of glass at an angle of 54½°, just under the circu ray polarised by reflection would not. Light, however, is neve by one refraction; but the proportion of polarised light in the re as the angle of incidence is nearer to the polarising angle; an tions through a number of surfaces of glass, or other mediu within any assigned limit of complete polarisation. A bundle or mica, bound together in a frame, forms a very convenient ap light, whether by refraction or by reflection.

3. *By Double Refraction.*—All crystalline bodies not belo system, possess the power of double refraction; that is t entering such a medium is split up into two rays of equal intensi crystal in different directions. In all such media, however, there directions in which double refraction does not take place, and the optic axes of the crystal. Transparent calcspar, or Iceland s in rhombohedrons, and exhibits double refraction more distinctl stance, is a crystal with one optic axis, the direction of that axis line joining the obtuse summits of the rhomb. A ray travers direction parallel to this axis is not divided into two; but in al ray is doubly refracted; and the two rays into which it is th completely polarised, the plane of polarisation of the one being pa *section* of the crystal, that is to say, a plane passing through t direction in which the ray traverses the crystal; the other in a to that section. The ray which is polarised in the principal sectio laws of refraction, remaining always in the plane of incidence, a cidences a constant index of refraction; but the ray polarised principal section follows different laws of refraction, its directio within the plane of incidence, unless that plane coincides with the principal section, and its index of refraction, excepting in th varying continually with the angle of incidence. The former o the *ordinary*, the latter the *extraordinary* ray. The mode of re will be more fully explained hereafter.

When these two oppositely polarised rays, which have traverse spar, fall on a plate of glass at the angle of 54½°, so placed that

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on of the crystal, the ordinary ray is reflected, and the
ntrary effect taking place when these planes are at
en the plane of reflection is inclined to the principal
and 90°, both rays are reflected, but with different

emerging from the crystal, will overlap each other, or
ccording to their breadth and the thickness of the
desired to examine only one of them, it is most con-
letely out of the field of view. This may be effected

atus for this purpose, called a **Nichol's prism**, con-
f calcspar (*fig.* 676), ABCD,
1 Canada balsam at the faces
ut so as to make an angle of
BF of the natural crystal (the
f 71° with the obtuse edges),
icular to AB and EF. With
at of the two rays, *no*, *ne*, into
rided, the ordinary ray, *no*, on
a balsam (whose index of re-
he ordinary, and greater than
suffers total reflection in the
dinary ray passes on in the di-
arallel to *mn*. An eye placed
mage, viz. that formed by the
eam of ordinary light passing
a plane perpendicular to the
, to the shorter diagonal of the
ay, already polarised, will be
e of polarisation is parallel to
it when the
licular to *ab*,
al *cd*. Hence,
l one behind
paque when
right angles
ent when the
and transmit
in interme-

Fig. 676.

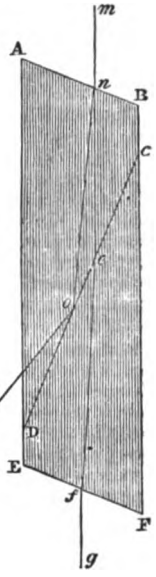
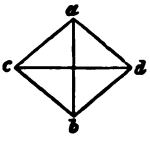


Fig. 677.



double-refracting crystals, espe-
he power of transmitting light only when polarised in a
to their optic axes. The tourmaline forms crystals be-
n, having one optic axis parallel to the axis of figure,
en polarised in a plane perpendicular to the optic axis.
larised by reflection from glass at the angle of 54½°, is
rmaline cut with its faces parallel to the optic axis,
th its optic axis perpendicular to the plane of reflec-
it as freely as its colour will permit; but if the tour-
parallel to the plane of reflection, the reflected rays
d no light will pass. If the tourmaline be gradually
sition to the second, the quantity of light which passes
ease, because the polarised ray is then divided by the
rised at right angles to the axis, the other parallel
former continually decreasing, and that of the latter
is turned round. When a ray of ordinary light is
ne plate of a certain thickness, cut as above described,
ther double-refracting crystals; but the ordinary ray is
the extraordinary ray passes through, so that the emer-
ed in a plane perpendicular to the axis of the tourmaline.
ourmaline be superposed, and the light of the sky be
the two be placed with their optic axes parallel, the
s freely as their colour and imperfect transparency will
alines be then turned round, the quantity of light trans-
s deviate more and more from parallelism, and at last,
another at right angles, the light will be completely

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Two such tourmalines mounted with their faces parallel to permit one of them to revolve in the plane of the axis, form a table apparatus for experiments on polarised light. A single convenient for examining light polarised by reflection or refr tion to the tourmaline is its colour, the best polarising tourm brown colour, which greatly modifies the colour of the transm in order that the tourmaline may polarise completely, it must least the tenth of an inch.

There are a few other double refracting crystals possessing particular the so-called "sulphate of iodo-quinine," discovered substance crystallises in thin six- or eight-sided plates, whi nearly colourless by transmitted light when viewed separately are superposed, with their longer dimensions crossing one ano part where they cross appears quite black, even if the thicknes exceed $\frac{1}{10}$ of a millimetre. The crystals of this compound n the same manner as tourmalines, and are even better adapted greater transparency and freedom from colour; but their fragi difficult to manipulate with them.

The best substitute for a tourmaline is the Nichol's prism, calcspar crystals being perfectly colourless and very transpare light than two superposed tourmalines.

All arrangements for examining the properties of polarised of two parts; viz., the **polariser**, by which the light is br state, and the **analyser**, by which its state of polarisation examined; thus, when a ray is reflected from a plate of glass the reflected beam examined by a tourmaline held before th is the polariser, and the tourmaline the analyser. It is cl apparatus above described, namely a reflector, a refractor, a d a tourmaline, or a Nichol's prism, may be used either as polar

Nature of Polarised Light.—The existence of rays ha on different sides was regarded by Newton as a decisive obje theory of light, on the ground that pressures or movements exc in an elastic medium ought to be equal in all directions; and to admit his inability to account for the existence of polarised theory as then understood. The reason of this apparent inab to explain the phenomena of polarisation, was that, at the tim ing, the vibratory movements of the ether were supposed to direction of propagation of the waves, and on that hypothesi ceive of rays of light, any more than rays of sound, possessin different sides. But later experimental researches, and the inv on the principles of analytical mechanics, have shown that th niferous ether take place in planes tangential to the wave-s the direction of the ray. From this point of view, the diffe and polarised light is easily explained. An ordinary or nat the vibrations take place in all directions successively in the p polarised ray is one in which the vibrations, still tangential confined to one plane. Suppose, for example, the direction of that of the wave-surface horizontal; then, if the ray be po vibration of all the particles will be either north and south, some one intermediate azimuth; and if it be unpolarised, place in all these directions successively.

This view of the nature of polarised light is established Fresnel and Arago on the interference of polarised rays, the g that *two rays whose planes of polarisation* (p. 653) *are paralle just like unpolarised rays: but two rays whose planes of polari to one another do not exhibit any phenomena of interferenc difference of phase.* These results are easily conceivable if the to the direction of the ray; for if the vibrations of the directions parallel to each other, the resultant will be equal of their individual movements, as explained at page 598, and that is to say, the rays will destroy each other, when their pha but if their vibrations are performed in planes inclined to c there will be, at every point, a finite resultant, determined in by the rule of the parallelogram of velocities, and never be Hence, two rays whose planes of polarisation are not parallel, to produce complete darkness; and if their planes are at righ they cannot interfere at all. If, on the other hand, the vibr

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e ray, it is impossible to conceive any conditions which terfering with one another, and producing darkness when a certain difference of phase.

ow that the interference of polarised rays does depend, as te of polarisation, are the following:

ugh two narrow parallel slits very close together, as in 9, 604), is polarised by covering the slits with two pieces ine, cut parallel to the axis, which polarises the light in a xis. If the two tourmaline plates have their axes parallel ns of light interfere and produce fringes, just as if the but if they are placed with their axes at right angles to disappear. In intermediate positions of the tourmalines ter as the angle between the axes approaches more nearly tourmalines, two small bundles of mica-plates may be position inclined to the direction of the rays, which are ost wholly polarised in a plane perpendicular to the plane then disappear when the bundles of plates are so placed nce are at right angles to each other.

red with two fragments of the same plate of calcspar or he optic axis. Each plate then gives an ordinary and an nes of polarisation are at right angles to one another. If ts are parallel, the two ordinary rays which emerge from s if they were unpolarised; so likewise do the two extra- systems of fringes are superposed. If now one of the lly turned round in the plane parallel to its axis, the when the axes of the two plates are at right angles to one ar altogether, and give place to uniform light. At the ystems of fringes make their appearance on the sides, ference of the ordinary rays proceeding from one of the rays from the other; they are shifted to the sides on elocity of the ordinary and extraordinary rays within the s of the two plates remain parallel, the ordinary ray of y ray of the other are polarised in planes at right angles al fringes are not produced; but on inclining the axes to inges appear, becoming more and more brilliant as the eases, and attaining their greatest brightness when the °.

, such as a hair, is placed in the path of the two rays land spar, placed before the focus of a lens, no fringes are w, as they would be by ordinary light, because the two at right angles to one another.

periment (p. 599), the rays are polarised by reflection in t of Young (p. 602), the rays originating from the same vibrations at each instant parallel to one another, so that n for interference.

s show then that the vibrations of the ether are parallel t in a polarised ray they take place, for the most part, in he ray. Moreover, *the vibratory movements are perpen- sation*. For when a beam of light passes through a crystal and spar, the *ordinary* ray is polarised in a plane parallel he crystal; that is to say, it is most easily reflected in a n (p. 653). Now as this ray follows the ordinary law of has a constant velocity whatever direction it may take rations of the ether which form it must have a constant axis of the crystal; and as they are perpendicular to the make with the axis, they could not form a constant angle were also perpendicular to that axis. The vibratory e ordinary ray are therefore perpendicular, both to the nd therefore to the principal section, which is the plane the axis, and in this case is identical with the plane of Hence, as all polarised rays possess the same properties, n, it follows that the vibrations of the ether are always at polarisation.

deduced from the properties of the tourmaline, which, as ntercepts the ordinary ray. Now it is found that a plate *ular to the optic axis*, intercepts all the light which falls idence, which shows that all vibrations perpendicular to

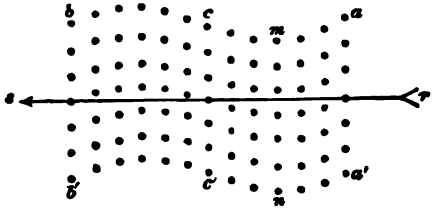
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the axis are arrested by it. But when the ray passes throu
cut parallel to the axis, only the ordinary ray is intercepte
passing through. The vibrations of the ordinary ray must th
to the axis, and consequently to the principal section of the
the ray is polarised.

From this direction of the vibratory movements, it follow
most easily reflected when its vibrations are parallel to the r
the contrary, that it is most easily transmitted through a
vibrations take place in the plane of incidence or at right angles
the ray passes most completely through a tourmaline cut para
vibrations are parallel to this axis. The tourmaline acts
which gives free passage to a surface, such as a knife-blade,
stops it when presented transversely.

The form of the curve which the ether-molecules describe i
to the direction of the ray—for example, in the row *a a'* (*f*

Fig. 677.



state of pol
the oscillat
motion of
wards and
line, the ra
nearly p
polarised
ing through
to the di
particles vi
polarisat
particles

the straight line which is the direction of the ray, appea
arranged in the wave-line *acb*. If each of the vibrating partic
direction of its velocity will change from 0° to 180° while t
through the space of half an undulation, and to 360° in th
lation: hence, a series of particles in all phases of velocity
tremity of the wave to the other, will be situated on a screw-
of the ray for its axis. The ray is then circularly polari
according as the direction of revolution of the ether-molecu
centre of the circle, or the axis of the screw, is like that of th
contrary. The result is the same as if the ray were polaris
plane revolved, making a complete revolution during the time

If each of the vibrating particles describes an ellipse, the
be conceived as arranged on an elliptical screw-line. In th
state of polarisation of the ray, it is necessary to specify, no
major and minor axes of the ellipse, but likewise the position
determined, for example, by a system of rectangular co-ordi
with the ray, while the other two are drawn at right angl
plane of vibration of the ether-molecules. The direction of t
stated as in the case of circular polarisation.

A circularly polarised ray examined by an analyser ex
in all azimuths, just like natural light, but is distinguished
coloured when viewed through the analyser, after passing th
double refracting crystal (p. 671). An elliptically polari
mum and minimum of intensity in two positions of the analys
other, but is never completely extinguished like a plane-pola
coloured by transmission through a double-refracting film. T
both to circularly and to elliptically polarised light, differ fro
similar circumstances by plane-polarised light.

To understand the manner in which these different states o
necessary to take account of the movement impressed upon th
when they transmit several systems of waves at once, th
compounded according to the principle of the parallelogra
composition is effected by construction or by calculation, it
lengths of the component waves are equal (the only case that
the waves of the resulting system always have the same len
produced can affect only the amplitude of vibration and the st

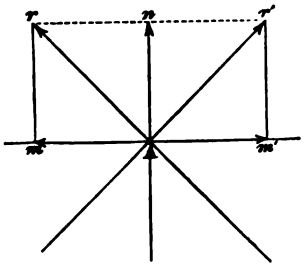
1. *When the two rays are polarised in the same plane.*—In
of the resultant wave is equal to the sum or difference o
according as the two rays are in corresponding or in opposite
in exactly opposite phases, and of equal amplitude, they dest

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ness. The case is, in fact, that already considered under

polarised at right angles to each other.—In this case, the systems take place in planes at right angles to one esulting system cannot be rectilinearly polarised, unless ie two component wave-systems is either nothing or an length. If we imagine two rays travelling at right angles nd passing through the point A (*fig.* 678), the vibrations ve of the one system *n*, and those of the f both the waves af- usly and with equal s will make an angle ponent wave. The is then 45°, reckon- ier hand, the second before or behind the e A with its negative me that the positive m begins to act. The -45°, always reckon-

Fig. 678.



ise of the two wave- r of a wave-length, s the particle A, just as the vibration imparted to it ght it to *n*, and it is about to return towards A: it movement round the point A. The ray is therefore or left, according as the system A*m* is before or behind f an undulation. If the amplitudes of the two systems iase amounting to a quarter of a wave-length will produce kind of polarisation is likewise produced with any other 0 or $m \cdot \frac{\lambda}{2}$), whether the amplitudes are equal or unequal.

rised in planes making an oblique angle with one another, 0 or $m \cdot \frac{\lambda}{2}$ produces rectilinear or plane polarisation, while es elliptical polarisation.

ng considerations, that elliptical polarisation is the usual ular and rectilinear polarisation being merely particular

ised ray to fall on the separating surface of two transpa- tion being inclined to the plane of incidence at an angle y then be regarded as resolved into a component (*P*) idence, and another (*R*) vibrating at right angles to that nents will be weakened by reflection in unequal degrees. ° (measured from the normal), the two components of the ensity; but from 90° to 0° the intensity of *R* continually *P*, though it likewise diminishes for a certain distance s a minimum value at a certain angle of incidence, whose fractive index, and increases again from that point up to

and also from non-metallic substances of high refractive

always a considerable value; but in the case of media of

power, such as water and glass, it very nearly vanishes at tioned. Moreover, as the variously directed vibrations of may be resolved into the two principal components above at the limiting angle, the vibrations of the ray (if mono- y all, be reduced to one plane—namely, a plane perpen- dence; in other words, the ray, after reflection, will be rly so, in the plane of incidence. The limiting angle the polarising angle (p. 653). It is clear also that if the a second mirror at the same angle, and this mirror is so f the polarised ray are parallel to its plane of incidence, lected from it; but that, if the second reflector be turned ays remaining at the same angle to the ray, the quantity

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of light reflected will gradually increase till the plane of incidence
mirror coincides with that upon the first, at which the quantity of lig
the second mirror will be a maximum. (See page 653.)

When light falls at the polarising angle on a substance of cor
refracting power, as glass, water, &c., the intensity of the refracted ra
than that of the reflected ray, inasmuch as a small portion of the
right angles to the plane of incidence, and nearly the whole of that
parallel to the plane of incidence, pass into the refracted ray. The f
unites with an equal portion of the latter, reproducing unpolarised l
refracted ray consists of natural light mixed with light polarised
incidence.

The two components P and R not only differ in intensity after ref
wise exhibit a difference of phase, P being always more or less beh
according to Jamin, in reflection from one or two varieties of silica.

At the incidence of 90°, since a ray polarised in the azimuth
azimuth unaltered, the difference of phase of the two components
nothing or equal to an entire wave-length (p. 659). At perpendicul
azimuth changes from 45° to −45°; consequently the difference of pha
cases, therefore, a plane-polarised ray remains plane-polarised after
at all other incidences, the difference of phase is between λ and $\frac{\lambda}{2}$, and
plane or rectilinear polarisation is converted into elliptical polarisatio
incidence for which the difference of phase $= \frac{3\lambda}{4}$ is called the princi
It is very little smaller than the polarising angle (p. 653), calculate
formula, $\tan i = \mu$: hence, at the principal incidence, the quotient $\frac{P}{R}$
from its smallest value. In substances of small refracting power, the
difference of phase $\frac{\lambda}{2}$ to λ takes place quickly, so that the elliptical po
ceptible only between very narrow limits; but in bodies of greater
such as diamond, it is more

Fig. 679.

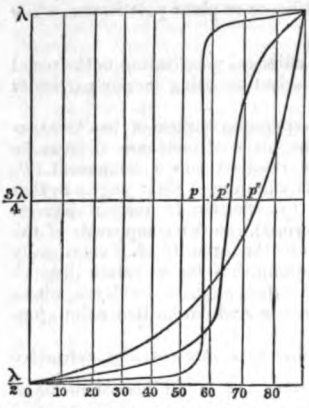


Fig. 679, in which the angles
laid down as abscissæ, and the di
diminished by $\frac{\lambda}{2}$ as ordinates, ex
ence of behaviour of glass, sulphi
zinc. The points p, p', p'' corres
cipal incidences, or to a differenc

The more refrangible rays acq
ference of phase in their two com
given incidence than the less refr
many metals, as silver, copper, b
silver, the ratio of the intensities
while in others, as zinc and steel,
more refrangible rays. In conse
equality, the former metals, esp
minated by light vibrating in th
tion, exhibit a yellow or red, th
colour, the tints often coming out
greater distinctness after repeate
the incidence of 90°, that is to say, when the incident ray just graz
well-polished metals appear white.

Theory of Double Refraction.

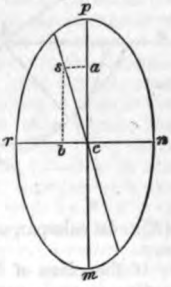
The phenomena of reflection, refraction, and coloration undergo co
tions when light falls upon media through which it travels with diffe
different directions. This is the case in all crystals not belonging
monometric system; likewise in all media whose molecular condition
ticular directions by pressure, or by heating and sudden cooling, such as

Crystals with one Optic Axis.—Consider, in the first place, crystals
dimetric and hexagonal systems, which resemble one anothe
optical as well as in their other physical properties, such as expansion

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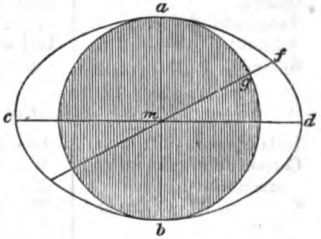
t and electricity (ii. 122). In these crystals, the elasti- greatest (negative crystals), or least (positive the principal crystallographic axis, but equal in all hat axis. If, now, from any point within the crystal, irections, and proportional in length to the square roots in these several directions, the terminal points of these face of revolution called the surface of elasticity hich rays are transmitted in these several directions, es to pass in all directions through the centre. Every elasticity in a closed curve, like ative—calcspar, for example—the lies in a meridional plane (called, ipal section), the shortest dia- f the surface of elasticity. If the vibrations take place in the di- ating through an extremely thin itself into two polarised waves, s of greatest and least elasticity, des ca and cb, and will there- cities in the direction perpendi- molecules of the ether were com- principal axis, so that a vibratory opagated in a direction oblique to two in the manner above men-

Fig. 680.



if the incident wave consists, not of polarised but of e two polarised components will then have equal inten- not only of the components of vibrations in the direction rations in all other directions within the plane $mnpr$. with the equatorial plane of the surface of elasticity, the equal. In this case, the light is not polarised in two another, but the wave travels onwards without dividing incipal crystallographic axis, which, on account of this ptic axis. Crystals of the dimetric and hexagonal xial.—If the plane wave passing through c coincides difference of the two velocities of transmission is a omponents calls into action the maximum amount of e axis itself. The velocity of transmission of the other ientioned, the same in all directions, inasmuch as it is ius, cr, of the surface of elasticity. If, now, we imagine ve-surfaces passing in all directions through the point c according to the laws above detailed, they will, after a curved surfaces called the wave-surfaces of mono- surfaces, corresponding to the light which vibrates in the les to the principal section (*i.e.* polarised in the principal ie second, corresponding to that which vibrates in the d at right angles to that section), is shown by calculation on, which touches ted on the optic section of the two n through such a t right angles to cities mg and mf. y are perpendicu- f the second are ane touching the , to find the velo- wave correspond- essary to draw a ane which touches

Fig. 681.

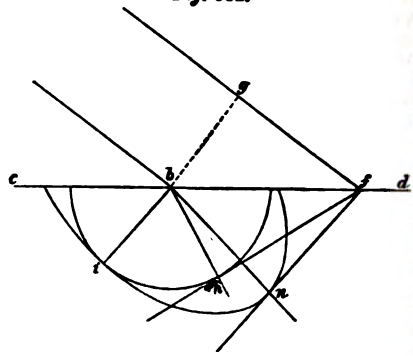


oped by Fresnel, all the phenomena of double refraction le manner. Suppose a beam of parallel rays correspond- 682) to fall upon the surface of a monoaxial crystal— ptic axis is in the direction bi. Round b as a centre so that, taking gf as unity, the radius of the spherical t of the ellipsoïd $\frac{1}{1{\cdot}483}$. Imagine also a line drawn

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through *f* at right angles to the plane of the figure, and planes to pass touching the sphere in *k*, the ellipsoïd in

Fig. 682.

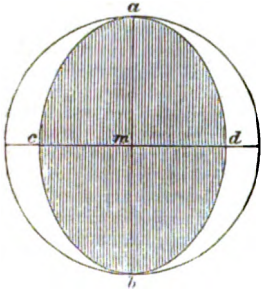


reference t
b n will be
refracted r
ray *bk* are
incidence,
principal s
are parallel
The ratio o
without an
pendent of
uncrystallis
longing to
phanous
sponding
This ray is
nary ray
fraction of
with the an
ray is called

(*E*). In calcspar, and all other negative crystals, it is les
ray.

If the plane of incidence neither coincides with a prin
ceding example, nor is perpendicular thereto, the plane dra

Fig. 683.



the ellipse will touch it in a
plane of incidence; the extra
from the plane of incidence,
ordinary refraction. As in
traordinary ray is always l
nary ray, and, in comparison
repelled from the optic axis, t
called repulsive: positive c
in which the extraordinary
the ordinary ray, are called

The optical relations of po
exactly similar to those of
that, as the elasticity of the
direction of the optic axis, t
this direction is a maximum.
ordinary ray encloses that of
shown in section in *fig.* 683. The ray *E* in these crystals
—is more strongly refracted than *O*.

The following is a list of the most important uniaxial crys

Positive or Attractive Crystals.

Zircon.	Apophyllite.
Quartz.	Sulphate of potassium and iron.
Tungstate of zinc.	
Stannite.	Acid acetate of copper and calcium.
Boracite.	

Negative or Repulsive Crystals.

Iceland spar.	Idocrase.
Carbonate of calcium and magnesium.	Wernerite.
	Mica.
Carbonate of calcium and iron.	Phosphate of lead.
	Arsenio-phosphate of lead.
Tourmaline.	Hydrate of strontium.
Rubellite.	Arsenate of potassium.
Corundum.	Chloride of calcium.
Sapphire.	Chloride of strontium.
Ruby.	Basic phosphate of potassium.
Beryl.	
Apatite.	

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given of double refraction in uniaxial crystals, it follows
l characterisation of such a body, it is sufficient to know
les of light therein, or—which comes to the same thing—
the two oppositely polarised rays which traverse the
lar to the axis. To find these indices of refraction, the
form of a prism, with its refracting angle parallel to the
ographic) axis, and the least deviations of the several
and extraordinary image measured by the methods already
found are, of course, true only for the particular tempera-
ired. Change of temperature likewise affects the refractive
rystals in a peculiar manner, because the rate of expansion
the direction of the optic axis, is not the same as in
hat axis. Calcspar, for example, expands in the direction
obtuse summits of the rhombohedron, more strongly than
ombohedron at the same time approaching in form to the
action perceptibly diminishes, or, in other words, the
E and *O* approach more nearly to equality. Very exact
refraction of Fraunhofer's seven lines (*B*—*H*), in the
images of calcspar and rock-crystal, together with the
by change of temperature, have been made by Rudberg
291). Double refraction is frequently also different in
oured rays. In apophyllite, indeed, this inequality is so
itively double-refracting for the blue, negatively for the
g for an intermediate ray.

axes.—In all crystals belonging to the remaining systems,
linic, diclinic, and triclinic, there are two directions
ry ray of light may pass without being split into two.
called bi- or di-axial. The somewhat more complex
bit are also completely explained by Fresnel's theory.
in these crystals is of unequal magnitude in three direc-
other (the three axes of elasticity). If we call the modulus
he middle b^2, and of the least c^2, and imagine lines drawn
l in all directions, proportional to the square roots of the
y in these several directions, the ends of these lines will
led the surface of elasticity, having three unequal
es to one another; and if plane waves be supposed to pass
rface in all possible directions, as in the case of uniaxial
ut the surface of elasticity in a closed curve. All vibra-
surface are very quickly resolved in the direction of the
s of the plane section, which are perpendicular to one
vided into two which travel onwards parallel to each other,
s, proportional to the square roots of the elasticities
the direction of those diameters. If all these plane
in motion at once, they will, after a given time, enclose
xial media.

ections of the wave-surface cutting one another at right
icular to the plane of the figure, the vertical section con-
a circle; the horizontal section, a circle enveloped by an
ane of the paper consists of an ellipse and a circle inter-
e represented separately in *fig.* 685. The circle in each
e vibrations are perpendicular to the plane of that section,
n of an axis of elasticity: such rays suffer ordinary refrac-
ner hand, gives the velocity of transmission of the extra-
ns are parallel to the plane of the section. To obtain the
e indices of μ, μ', μ'' of a biaxial crystal, three prisms must
g angles respectively parallel to the three axes of elasti-
ation of the seven principal rays determined in each of
o coloured images, whose plane of polarisation is perpen-
le. This measurement has been very carefully performed
and topaz. Both the refractive indices, and the ratios
temperature in biaxial as well as in uniaxial crystals.

express the strength of the double refraction, appear to

the less to the more refrangible rays. In crystals of the
elasticity have the same direction for all the coloured rays.
di-, and tri-clinic systems appear to exhibit a different

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behaviour in this respect. Their peculiarities will be considered
the colours which they exhibit in polarised light (p. 669).

Fig. 684.

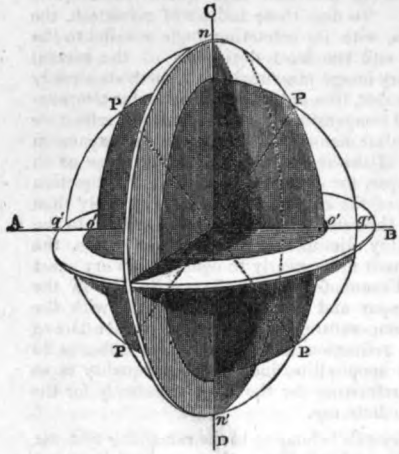
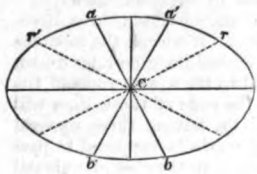


Fig.



In two directions, *ab* and *a'b'* (*fig.* 686) making equal angles with t
and also with that of least elasticity,
ticity is cut in circles. At right ang
these circles, and therefore in the di
plane wave is propagated without b
others, or altered as to its state of p
directions were designated by Fresnel,
axes of the crystal. But, as shown
are likewise two directions in which
extraordinary rays, which, therefore,
waves, are transmitted with the sam
directions, which unite the points of in



ellipse and circle with the centre M, have received the name of
axes.

As may be seen from the figure, it depends upon the ratio of th
transmission M*q* to the greatest M*n* and least M*o'*, whether the a
form a smaller angle with the axis of greatest elasticity and leas
mission, or with that of least elasticity and greatest velocity of tra
former case, the crystal approximates in its optical character to calc
fore called optically negative (*e.g.* arragonite); in the latter, t
is therefore called optically positive (*e.g.* topaz). The line
acute angle of the optic axes is the median line; that which b
angle, the supplemental line; and the line perpendicular to bo
normal. The last is always the axis of mean elasticity; the me
with the axis of greatest elasticity in negative, and with that of
positive crystals.

To find the rays belonging to a given plane wave-surface, plan
parallel to this plane and tangential to the wave-surface, and the
joined with the centre. This construction always yields two tangent
fore two rays. It is only when the wave-plane is perpendicular to o
axes, that the two tangent planes coincide in one, which, however
wave-surface in a circle. At the point P (*fig.* 685), the wave-sur
shaped depressions or re-entering cones, the plane wave RS, which i
the true optic axis MT, closing the funnel and touching the curved
circle having the diameter QT. To this wave-plane, therefore, c
proceeding from the centre M to the several points of the circumfer
If, therefore, a ray of common light falls upon a plate of arragonit
at right angles to the median line, in such a direction that it wo
direction of the true optic axis, it divides itself into a conical beam
they belong to the same wave-plane, proceed, after emerging, para
in a cylindrical beam. This phenomenon, the so-called cylin

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s perceptible only when the arragonite plate has a re.

centre to the surface of the wave, *e.g.* MT or MQ, cuts sponding to the two rays which travel in this direction. these rays are found by drawing tangent-planes to the e upper wave-surface. It is only the ray MP, which pparent optic axis, that cuts the wave-surface in a single ver, the wave-surface has an infinite number of tangent ace the velocity of the wave-plane within the crystal e refraction, the ray MP yields an infinite number of one another in a cone. This remarkable phenomenon, fraction, may be observed by covering the two parallel ut perpendicular to the median line, with screens, each ed that the line joining the two apertures coincides with ystal. If a converging pencil of rays from a near source e of the arragonite plate, a conically divergent pencil

of the two rays proceeding in any given direction are be made to pass through the ray and the two apparent ration of the one ray bisects the acute, and that of the he two planes. The directions of vibration (and there- tion) of the two rays are therefore always perpendicular

efractive indices, μ, μ', μ'', of a crystal are known, and as shown, the angle 2β of the true optic axes may

ve crystals. For positive crystals.

$$\sin^2\beta = \frac{\mu''^2 - \mu'^2}{\mu''^2 - \mu^2}; \qquad \sin^2\beta = \frac{\mu''^2}{\mu'^2} \cdot \frac{\mu'^2 - \mu^2}{\mu''^2 - \mu^2};$$

rent optic axes by the formulæ:

$$= \frac{\mu''^2 - \mu'^2}{\mu''^2 - \mu^2}; \qquad \sin^2\alpha = \frac{\mu'^2 - \mu^2}{\mu''^2 - \mu^2}.$$

ive crystals, the apparent optic axes form a somewhat ic axes, whereas in positive crystals the contrary is the

BLE OF BIAXIAL CRYSTALS.

Angle of axes.			Angle of axes.	
eci-		Sugar	50°	0′
3°	0′	Sulphate of strontium	50	0
5	20	Sulphohydrochlorate of magnesium and iron	51	16
6	56	Sulphate of magnesium and ammonium	51	22
6	56	Phosphate of sodium	55	20
7	24	Comptonite	56	6
10	35	Sulphate of calcium	60	0
11	28	Nitrate of silver	62	16
13	18	Iolite	62	50
18	18	Felspar	63	0
19	24	Sulphate of potassium	67	0
27	51	Carbonate of sodium	70	1
28	7	Acetate of lead	70	25
28	42	Citric acid	70	29
35	8	Tartrate of potassium	71	20
37	24	Tartaric acid	79	0
37	42	Tartrate of potassium and sodium	80	0
37	40	Carbonate of potassium	80	30
38	48	Cyanite	81	48
40	48	Chlorate of potassium	82	0
41	42	Epidote	84	19
42	4	Chloride of copper	84	30
44	41	Peridote	87	56
45	41	Succinic acid (about)	90	0
45	8	Sulphate of iron (about)	90	0
um 46	49	Mica	0° to 76	0
45	8			
to 65	0			

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It will be observed that topaz, and more especially mica, in different specimens. Sénarmont explains this anomaly b mixtures of two isomorphous substances, in which the pla dicular to each other. He has shown, in fact, that a crystal substances has its axes more or less inclined to one another, position varies by 90° from one specimen to another, acco the mixture. In the case of mica, which, as Sénarmont right prisms with rhombic base (trimetric), the plane of the to the longer, sometimes to the shorter diagonal of the *Physique*, iv. 489.)

Reflection of Light from Double-refracting Media.—The surface of double-refracting crystals follows, so far as rega of the two principal components polarised parallel and p incidence, the same laws as those which are observed in reflec

On the other hand, the alterations in the azimuth of pola the angle of incidence, but likewise on the inclination of th plane of incidence to the axes of the crystal. Even when dicularly on a double-refracting surface, the azimuth of po unaltered. In particular cases, however, no alteration ta uniaxial crystals, when the reflecting surface is perpendicul the plane of incidence coincides with the principal section. of the reflecting surface and the plane of incidence, there dence at which the azimuth remains unaltered. It must a light is reflected within a double-refracting medium, ea reflected rays; that in uniaxial crystals, only one of the stantly in the plane of incidence, whereas the other may d in biaxial crystals, for the most part, neither of the two r plane of incidence.

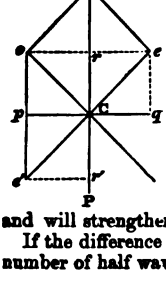
Colours of Polarised Ligh

Double-refracting substances viewed in polarised light of the exact observation of which affords, in most cases, an es the position of the axes of the crystal, than the mere separ two, which is distinctly perceptible only when the double r crystal has a considerable thickness. Hence, the observa nomena is of great service in the study of crystalline struc

Since the two rays into which an incident ray of common a double-refracting medium travel through that mediu (p. 661), they will, on emerging from the medium, exhibit a As, however, the vibrations of the two rays always take pla to one another, they cannot interfere so as to produce any c tensity. Hence, the two images seen through a double-re light are colourless.

But the case is different when the crystalline plate is vi ratus, say, between two tourmalines, or two Nichol's prism the other as analyser (p. 655). The rays which fall on this the action of the first prism or tourmaline, that is to say, t to one plane. If this plane is parallel to one of the dir double-refracting plate, they pass through it without furt only one ray—ordinary or extraordinary, as the case may be But if the direction of vibration CP (*fig.* 687) of the polari

Fig. 687.



two directions of vibration Co, Ce, of two components, Co, Ce, of equal intens now that the difference of path of the tw passing through the plate, is equal to a lengths; the vibrations will then proc towards *o* and *e*; and if the direction of lyser is at right angles to that of the Co, Ce, will then yield two equal and Cq, which will destroy one another. C light is monochromatic, the field of vi analyser, will be dark. If, on the oth analyser are placed with their axes paral CP, the components of Co and Ce will and will strengthen one another, so that the field will be li

If the difference of path of the ordinary and extraordinar number of half wave-lengths, the vibrations will proceed fr

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equently, the phenomena just described will be exactly
: when the axes of the two tourmalines or Nichol's prisms
they are crossed.

s white, it is only particular coloured rays that destroy
strengthen one another's effect in the greatest degree;
er dark, but the double-refracting plate appears coloured,
g to the thickness of the plate; and for any particular
ary to one another in the two relative positions of the
en a double-refracting prism (p. 655) is used as analyser,
ours of which are complementary to one another; and if
rsect, the overlapping portion is white.

ed plate of a double-refracting crystal—gypsum, for ex-
the crossed Nichol's prisms or tourmalines, a series o
following exactly the order of colours of Newton's rings
rt, the wedge is colourless, because there the difference of
nall fraction of the wave-lengths of all the coloured rays.
kness, the violet and blue rays disappear first, and the
ish white and orange into red of the first order. Beyond
rays disappear, and a blue stripe is produced, and so on.
at that the difference in length of path of *o* and *e* amounts
engths of a great number of rays diffused through the
ing rays together produce white light: hence plates of
above a certain thickness, no longer appear coloured in
the white light which has passed through such a plate be
resulting spectrum is seen to be traversed by a great

Nichol's prisms are placed with their axes parallel, the
ementary to those above described; hence it is clear that
produce any colours in double-refracting plates, inasmuch
all possible azimuths, so that the colour produced by any
is exactly compensated by the complementary colour of
the first, the two together reproducing white light.

hich a circular cavity of very long radius is made, exhibits
coloured rings exactly similar to Newton's rings.

any crystalline plate in polarised light may be determined
escribed wedge, in such a manner that the *o* of the plate
of vibration with the *e* of the wedge. At the place where
equal differences of path, their actions compensate one
e is seen with the tourmalines crossed, and a white stripe
der of the colour may then be read off on the wedge.

d the plate to be placed at right angles to the rays. On
olours change—first, because the rays have then to pass
of the plate; secondly, because the angle which the rays
of the crystal also varies, and this circumstance likewise
corresponding to a given thickness of the crystal.

late of a double-refracting crystal cut perpendicularly to
he colours above described when viewed by parallel rays,
he axis, the two rays *o* and *e* have equal velocities, or, in
one ray. But, when diverging light, proceeding from a
tance, is made to pass through the crystalline plate placed
when the analysing tourmaline is placed so

Fig. 688.



al rays converge strongly towards the optic
-coloured rings are produced, the form of
e crystalline plate is uniaxial or biaxial.

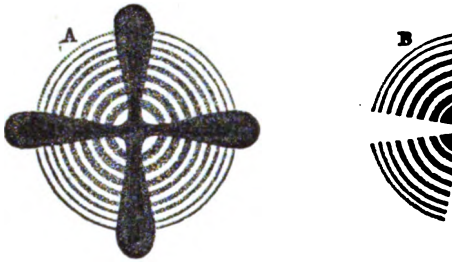
ewing these phenomena consists of two plates
tating in their own planes in two rings, or
to the end of a spring, *c*, so that the crystal-
e of cork, may be firmly held between them,
ng round in its own plane.

rystal, such as calcspar, cut with parallel
ptic axis, exhibits, when viewed between the
of circular coloured rings, intersected by a
n the other hand, the tourmalines are placed
e cross is white, as in *fig.* 690, and the
o the former. To understand their forma-
ry to remember that, in the direction of the axis *ba*
c have equal velocities, but that their difference of

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path becomes greater and greater in proportion as they are m
because, in the first place, the difference of velocity of the two

Fig. 689.



unually greater; and, secondly, because the thickness of the
traversed by the rays increases at the same time. The colou
above described (p. 667), are arranged parallel to the edge are
concentric circles round the axis, the order of the tints being
rings.

The vibrations parallel and perpendicular to the axis of the
being resolved into two components, there can be no interfer
through the centre of the field in those directions. Hence the
cross when the tourmalines are crossed, and of the white or
parallel.

The rings are closer together in proportion as the double ref
the thickness of the plate greater.

The colours of the rings change, to a certain extent, accordin
of double refraction for the different coloured rays. A very pe
respect, is exhibited by apophyllite, which, as already observed,
and negative for the red rays.

A plate of a biaxial crystal, cut at right angles to the r
between two tourmalines, in such a manner that the plane of t
to the axis of one of the tourmalines, exhibits, when the tourm
system of rings delineated in *fig.* 691. The mode of formation of th
as that above explained with regard to uniaxial crystals. But,
of the rays *o* and *e* increases with their inclination to both the
colour embrace both these axes. The form of these rings is ne
cate, a curve distinguished by the property that the product of
drawn from the two poles to any point of the curve, is a constan
the double-refracting plate round in its own plane, the whol
round in the same direction, and the black cross separates into t

Fig. 691. *Fig.* 692.



the appearance shown in *fig.* 692; and when the plane of th
of 45° with the axes of the two tourmalines, the two black
hyperbolas, as in *fig.* 693. The general direction of the bran
is always parallel or perpendicular to the plane of primitive
tinuing the rotation of the plate from 45° to 90°, the same ap
in the reverse order, and the whole series of changes is repea
quadrants.

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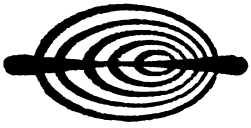
alyser are placed with their axes parallel, the form of the xactly the same as above, but the colours are complemen-

sent the appearance in crystals, such as nitre, which have small angle not exceeding 5° or 6°; when the axes are gure can be seen at once.

nce of the rings formed by a biaxial crystal cut perpen- xes.

lours in the neighbourhood of the axes shows plainly ion of the axes increases to the red rays. The for- f potassium, the latter in stals of the monoclinic, as ystems, even the direction different for the different um, diopside, and cupric nedian line varies accord-

Fig. 694.



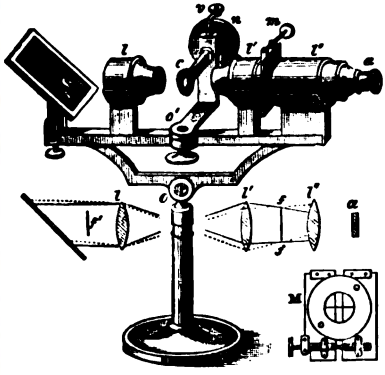
dularia, tarturic acid, and acetate of sodium, the different line, but differently directed ordinates, so that the planes frangibility of the light.

hibited by many biaxial crystals are altered in a very e of temperature. Glauberite, for example, is uniaxial at olet light, but biaxial for all other colours. At lower lso splits into two, and the angles between the axes of the on the other hand, the temperature is raised, the violet ne at right angles to the former; the axial angles of the ne nothing, and then likewise pass into the perpendicular tuated together, even before the temperature rises as high

.—The form of the curves, and of the dark bands which neans of determining the position of the axes in biaxial of the plane of the optic axes, the crystal, cut in the form , is placed between a polariser and analyser with their so as to produce darkness, and the plate is turned round ence does not restore the light. Two positions are thus f the primitive plane of polarisation are to be marked on two traces form a right angle, and one of them is situated e plate is then turned round in its own plane, till each of f 45° with the primitive plane of polarisation; then, by l these traces, a position is sought in which the rings can s. The plane of the axes is perpendicular to the line en turned to discover the rings.

between the Axes.—The most convenient apparatus for this asurements of Soleil,

Fig. 695.



by reflec- h may be ination by through a a focus on e the rays diverging gh an eye- the focus he curves this image nd the an- icrometer, M. It has ne another, nd capable separated is right-, and the other left-handed. The plate *c* is held g on a horizontal axis, its rotation being measured by a vernier which is read off by the magnifier *v*. The sup- able of turning on *o*, so that the crystalline plate *c* may sition.

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To measure the angle between the axes, it is best to use h crystalline plate *c*, cut nearly at right angles to the median li in such a position that the plane of its axes may be vertical, round in its own plane, so as to bring each of the poles succ the intersection of the wires of the micrometer. The arc thr turned between the two positions gives the observed angle 2 optic axes (p. 664). From this the real angle between these a equation $\sin a' = \mu' \sin a$, in which μ' is the middle of the three indices for the coloured ray observed.

Soleil's apparatus serves also to measure the diameters of th being capable of turning round on itself, the diameters can ea required direction.

Double-refracting structure produced by Molecular Tensi other amorphous bodies, also crystals belonging to the reg double-refracting structure, when pressed, stretched, or heate parts, and exhibit, when examined by polarised light, colours produced by double-refracting crystals. A rectangular plate on a very hot iron plate, exhibits, when examined in a polarisi coloured bands parallel to its edges, these bands altering th heat is gradually conducted across the plate, and disappea becomes uniformly heated all over. A similar effect is produ in the same manner on a plate of metal cooled by a freezing m it to lateral compression.

These effects are, however, most strikingly exhibited by u to say, glass which has been heated and quickly cooled. G irregular structure, the parts near the surface having been m the interior parts, and torn away from them, as it were, by th cooling. In consequence of this irregularity of structure, th refraction on all rays which traverse it, but in different degr whence there results a variable coloration when the glass is vi The figures produced exhibit a symmetry depending on tha plate. A circular plate of unannealed glass, the structure o round the axis, acts like a uniaxial crystal, exhibiting concent a black or white cross, according to the relative positions of th If the structure is not quite symmetrical round the axis, the torted. A square plate exhibits a cross with coloured frin elliptical plate exhibits a figure resembling those of biaxial cr

Absorption of Light by Double-refracting Crys

Certain coloured double-refracting crystals, when traversed exhibit different colours according to the direction of the rays w thus dichroïte or iolite (ii. 320) appears of a yellowish white co or of a fine azure blue, according as the rays traverse it parall axis; in like manner, chloride of palladium and potassium exhi or a fine green colour; some varieties of sapphire are blue or green tourmalines appear dark brown-red when viewed along t

This effect is due to the property possessed by double-refract polarised rays in different proportions according to the inclin regard to their axes. The tourmaline absorbs completely all parallel to its axis, and transmits them in greater and greate is inclined to the plane of polarisation; moreover it absorbs posing white light in the same proportion, consequently the t always of the same colour, excepting in the case of the green tioned. But when the absorption-coefficients of the several ferent proportions with the change of direction of the rays formed by the mixture of the unabsorbed rays likewise varie to the axis.

Some biaxial crystals exhibit trichroïsm; thus certain B lowish rose tint in the direction of the median line, are violet complementary line, and yellowish white perpendicular to the

Babinet has observed that, of the two rays into which an i entering a uniaxial crystal, that which travels most slowly a fracted, is also absorbed in the largest proportion; in positive as tourmaline, it is the ordinary, and in negative crystals, like extraordinary ray which is most absorbed. This law, true in cases, nevertheless admits of numerous exceptions. Thus, Ha

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ent in the blue and yellow varieties of beryl, although
ed that acid chromate of potassium, cyanite, and certain
ptions to the rule; and that idocrase and cupric acetate,
s the blue rays, deviate from it as regards the yellow,

ne following laws regarding the absorption of light by

ecrease of intensity in geometric progression as the
ic progression (p. 636), holds good for double-refract-
nedia, so that the ratio $o : e$ likewise varies according to

ious function of λ, exhibiting, in all the crystals observed,

equal on either side of the maximum or the minimum;
imum occurs at a particular wave-length λ', the values
equal.
e position of the maximum and minimum depend upon
regard to the axes of the crystal.
ion of the function $o : e$, it is probable that in crystals,
net's law, the exception applies only to certain rays of

ircular Polarisation.

out (p. 658), that when two rays of light travelling along
planes at right angles to each other, and differ in phase
then if the amplitudes of vibration of the two are equal,
wave vibrate in circles transversely to the direction of
is said to be circularly polarised, and the pheno-
same as if the ray were polarised in one plane, and that
d the direction of the ray as an axis.
oited in a remarkable manner by quartz, in which
te of this substance (which is uniaxial) cut at right
oits when viewed between two tourmalines or Nichol's
a system of coloured rings similar to those produced by
e of the field of view, instead of exhibiting a black cross,
colours, red, yellow, green, blue, &c., according to the
rning the analyser on its axis, the colours in the centre
ic series from red to violet, or the contrary, according
t no alteration of colour is produced by rotating the
ser remains stationary.
nena, we must examine what takes place when homo-
e, then, a plate of dark red glass coloured with red oxide
veen the two tourmalines or Nichol's prisms, crossed as
mitted by the analyser. If the plate of quartz be now
tely makes its appearance, and to render the field again
e analyser through a certain angle, either to the right or
hat the ray which has traversed the quartz must have
cted through an angle equal to that through which the

produced with yellow, green, violet, or any other kind
e angle of rotation varies according to the nature of the
eatest for violet light.

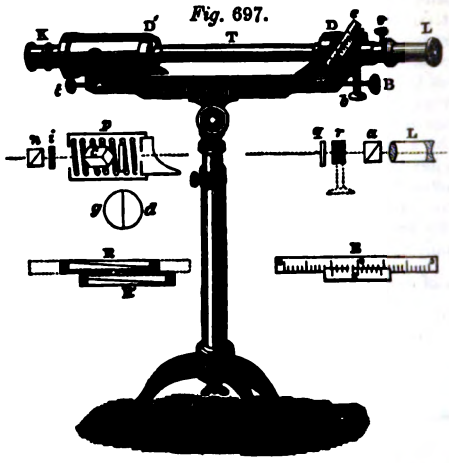
	Angle of rotation.	
	Plate 1 mm. thick.	Plate 3·75 mm. thick.
. . .	15°	56½°
. . .	19	71¼
. . .	24	90
. . .	27	101¼
. . .	32	120
. . .	38	142½
. . .	44	165

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error may arise from the different angles of rotation imparte
rays.

To obviate this source of inaccuracy, a contrivance calle
been invented by Soleil, which, together with the other part
a saccharimeter, being especially adapted to the esti
saccharine solutions—is represented in *fig.* 697. The tube T

Fig. 697.



solu
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it is
sho
arra
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n,
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mill
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half
othe
The
doul

the tube T, arrives at a quartz-plate, *q*, cut perpendicular
through the compensator, *r*. is analysed by the double-re
finally viewed through the small telescope, L L.

RR' is a horizontal section of the compensator, consist
perpendicular to the axis, and of contrary rotation to the p
slide one over the other horizontally, and in contrary dire
thickness which the modified light has to traverse. The
toothed pinion fixed to the button *b*, and acting on two rack
of the mounting of the prisms. One of these mountings
represented separately at E; the other, a vernier, which s
serves to measure the opposite displacements of the two pris
scale and vernier coincide, the two prisms are opposite to or
nesses are together equal to that of the plate *q*, the rotatory
neutralised by them. The analyser may then be turned by
v, into such a position, that the two halves of the double qu
the sensitive tint. If the tube T, containing the liquid, b
two halves, *g*, *d*, will then exhibit very different colours; and
the compensator, *r*, must be so adjusted as to produce, tog
inversion opposite to that of the liquid, either by increasing
prism, *r*, or diminishing it, so as to allow the action of t
The direction in which the vernier is moved along the rule,
series of divisions on opposite sides of the zero point, in
rotation exerted by the liquid, and the displacement of the
deviation when the thickness of quartz corresponding to
known. These divisions are usually made to correspond
metre; the vernier indicates the tenth of these, so that th
to the hundredth of a millimetre. The half of this quan
appreciable difference of tint in the two halves of the doubl

When either the light, or the liquid in the tube, is coloure
produced by the polarisation, modifies the sensitive tint, a
of the observation. To neutralise this colour, Soleil places
instrument, a double-refracting prism, *n*, and a quartz-plate
can be turned round in its own plane by means of a toot
the button B. This plate is interposed between the two pr
which acts as analyser, and yields a colour which may be v
n, so that a position of this prism may be found which give
neutralising that of the liquid, or of the light employed.

As the apparatus above described requires the observatio

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plied to liquids which disperse polarised light according
s shown that this is the case with saccharine solutions,
atus is especially adapted; but with other liquids, such
ose rotatory power for the different coloured rays
72), the observation of the transition-tint does not give
ls it is best to resort to the simpler mode of observation
sing homogeneous light.

atory power and Crystalline form.—Circular polarisa-
tain want of symmetry in the molecules of the medium
in fact, all crystals which exhibit circular polarisation
. This is remarkably the case with quartz, which is
e rhombohedrons + R and − R with the hexagonal
of it exhibiting hemihedral and tetartohedral com-
ii. 143, *fig.* 258). Moreover the six faces y ($6P\frac{5}{3}$),
o those
placed
als on
ve, and
rary in
, 699.
duced,
umber
le, but
flected
tals of
tatory,
otatory
pposite
a cor-
cal ro-
other
larisa-

Fig. 698.

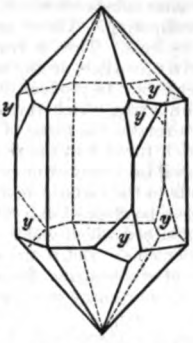
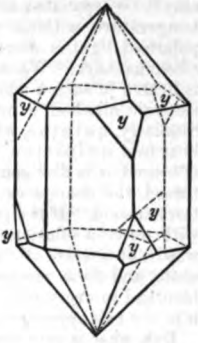


Fig. 699.



s turn the plane of polarisation to the right; racemic
nical composition with tartaric acid, and agrees with it
ons, has no action whatever on polarised light, either in
ed with bases. Now, the crystals of tartaric acid and
those of racemic acid and the racemates, with one
e exception alluded to is the racemate of sodium and
mate of sodium and racemate of ammonium, in equiva-
oration, crystals of a double salt, the form of which is

prism, P, M, T,
ced by the faces
latter faces, with
. If the crystal
be eight of these
low; but, as the
r of them, placed
hemihedral faces
not similar, but
s in the case of
is, as it were, the

Fig. 700.

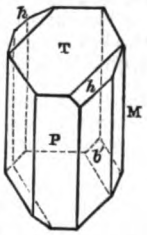
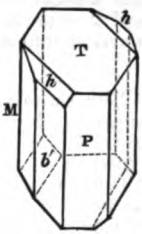


Fig. 701.



picking out the
dissolving them
e obtained which, at the same degree of concentration,
s upon polarised light, the one deflecting the plane of
ther, by an equal amount, to the left. Moreover, the
handed crystals, yield by evaporation, crystals, each of
ixing the solutions of these crystals with chloride of
ined, which, when decomposed by sulphuric acid, yield
in composition, and in every other respect, except that
pposite hemihedral modifications, and their solutions,
ee of concentration, exhibit equal and opposite effects

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Of the two acids thus obtained, the one which turns the plane of right is identical in every respect with ordinary tartaric acid; the ot tartaric acid. The two acids are also distinguished as dextro- an dextro- and lævo-tartaric acid. When equal weights of these two in water, and the solutions mixed, a liquid is obtained, which has on polarised light, and yields by evaporation, holohedral crystals of r similar result is obtained by mixing equal quantities of any of th acids, excepting the double salt of sodium and ammonium.

Hence it appears that racemic acid, a body which has no action up and crystallises in holohedral forms, is a compound of two acids (ta taric), which have equal and opposite effects on polarised light, similar but opposite hemihedral forms. These acids differ also in relations. The crystals of both become electric when heated, but extremities of the two exhibit opposite electrical states. Racemic electric.

Tartaric acid may be converted into racemic acid by the actio only it be associated with some substance which will enable it to bea temperature without decomposing. There are many substances polarised light is altered by heat. This is remarkably the case wi cinchona bark. When cinchonine, or any of its salts (which ro is heated in such a manner as not to produce decomposition, it is t isomeric alkaloïd, cinchonicine, which turns the plane of polar Similarly, quinine, which rotates the plane of polarisation to the l heat into quinicine, which turns it to the right. Now, when tar is heated, it is first converted into tartrate of cinchonicine, and if th tinued, the change extends to the tartaric acid, half of which is c tartaric acid. If the process be stopped at a certain point, and the with water, a solution is obtained which yields, first, crystals of anti wards, of tartrate of cinchonicine. But if the heat be longer contin unite, and form racemate of cinchonicine, from which racemic acid identical in every respect with ordinary racemic acid, and separable into the two opposite tartaric acids.

But, what is very remarkable, there is formed at the same time tartaric acid, which has no action whatever on polarised light, and y into the two opposite acids. In fact, when the fused mass obtained of cinchonine is treated with water, and chloride of calcium adde formed, consisting of racemate of calcium, and the filtrate, if left at re of the calcium-salt of inactive tartaric acid.

There are other organic compounds, which are also optically activ forms, but exhibit inactive and inseparable modifications. Malic in fruits, turns the plane of polarisation to the right; so likewise doe obtained by the action of acids and alkalis on asparagin. Now, bo be formed from fumaric acid, an optically inactive substance. Acid nium is $C^4H^3(NH^4)O^4 = C^4H^7NO^4$, which is also the formula of asp acid is actually formed by heating the acid fumarate of ammonium. acid thus produced is, like fumaric acid, optically inactive. Agai converted into malic acid by the action of nitrous acid:

$$C^4H^7NO^4 + HNO^2 = C^4H^6O^5 + N^2 + H^2O$$

Both active and inactive aspartic acids undergo this transfor aspartic acid yields active malic acid, and inactive aspartic acid yi acid. Neither inactive aspartic nor inactive malic acid can be separ oppositely active.

Common oil of turpentine possesses considerable dextro-ro the isomeric substance obtained by heating the artificial solid cam with quicklime is optically inactive.

Fusel oil has been shown by Pasteur to be a mixture of tw alcohol, which differ slightly in boiling point. One of these acids the other inactive.

Circular Polarisation induced by Magnetic action.—Faraday, in portant discovery, that bodies which, in their ordinary state, e action on polarised light, acquire the power of circular polarisation, the influence of powerful electric or magnetic forces. A polarised the axis of a prism or cylinder of a transparent substance, such as its plane of polarisation deflected to the right or left, as soon as jected to the action of an electric current passing round it at right or to that of two opposite magnetic poles (permanent or electro-m

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ncides with the direction of the ray. The rotation ceases
gnetic force ceases to act; its amount varies directly as
d its direction changes with that of the current or of the
um has a rotatory power of its own, the total effect is
e of the natural and induced rotations, according as the
cts with or against the natural rotatory power of the
Trans. 1846, p. 1.)
ena, which led to the discovery of the universality of
been followed out in greater detail by Pouillet, E. Bec-
sen, Verdet, and others.
xli. 370; xliii. 37) has confirmed Faraday's result relat-
the rotation to the magnetic force; and has also shown
acts obliquely to the ray, *the rotation of the plane of*
the cosine of the angle contained between the direction of
tic action; in other words, *the rotation is proportional to*
force which is parallel to the ray. In accordance with
when the direction of the magnetic force coincides with
l to nothing when it acts at right angles to the ray.
Faraday found that the direction of the induced rotation
ng electric current, or of an electric current which would
larity. This law is true with regard to all diamagnetic
nown that in certain magnetic bodies the direction of the
o that of the current. This inverse or *negative* rotation
ron, titanium, cerium, and lanthanum; whereas those of
m exhibit *positive* rotation, that is, in the same direction
ganese salts, some exhibit positive, others negative rota-
rric chloride, which exhibits negative rotatory power, is
sitive, the negative rotation actually produced increases
ion; the same salt dissolved in alcohol, ether, or wood-
ss positive solution than water, exhibits a still greater

f different substances.—All the liquids and transparent
Faraday experimented, exhibited more or less magnetic
to Matthiessen (Pogg. Ann. lxxiii. 65, 71; Compt.
is power is not exhibited by fused phosphoric acid, flint,
Crystallised bodies in general do not exhibit it; rock-
it in a very high degree. Mercuric chloride, carbonate of
e quite unsusceptible of magnetic rotatory power, when
ngly in the amorphous state.
-silicate of lead) was formerly regarded as the substance
gnetic rotatory power; but Matthiessen has shown that
hibit it in a still higher degree. The greatest rotatory
ates, and perhaps by the chlorides. Among bases, oxide
introduced into glass, produces the greatest increase of
follow the oxides of bismuth, antimony, zinc, mercury,
d baryta do not appear to exert any influence; lime,
effect.
] xxiii. 5) has obtained the following values of the mag-
al substances, as compared with that of Faraday's heavy

. .	100	Trichloride of phosphorus . .	51
. .	87	Solution of chloride of zinc . .	55
. .	89	Solution of chloride of calcium .	45
. .	53	Water	25
. .	77	Alcohol at 36°	18
. .	74	Ether	15

fferent coloured rays by magnetic rotation in flint-glass
ine (Wiedemann), follows the same laws as in circular
tz (p. 672).
atory action.—Faraday at first attributed the observed
the magnet on the rays of light; but further research
on of the plane of polarisation is due to a temporary
structure of the transparent medium, induced by the
et. In accordance with this view, it is found that any
olecular displacement, likewise impedes the development

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of the rotatory power by magnetic action: hence it is that developed in crystals. The development of this power is li sure, but favoured by heat, which increases the spaces bet thereby facilitates their displacement by magnetic action.

LIGHT, CHEMICAL ACTION OF. A large nun chemical change on exposure either to sunlight or to certain the action thus effected is said to be chemical action induced b or mechanical theory of light and heat easily explains this inasmuch as this theory supposes, in accordance with the prin of energy, that the rapid vibrations of the luminiferous ethe term light, are transferred to the smallest particles of the producing the chemical change. Amongst the most striking changes effected by the action of light may in the first place by light upon the salts of silver, giving rise to all the marvellou and secondly, the conversion of the carbonic acid gas contain stituent elements, by plants in sunlight, a chemical decomp whole living world depends.

The peculiar blackening which exposure to light effects up observed as early as the middle of the sixteenth century, bu phenomenon was first given by Scheele in the year 1777 (*Feuer*, Leipsic, 1784, p. 64). He clearly proved that when chl to light a black substance, insoluble in ammonia, but soluble i at the same time hydrochloric acid is set free; and hence Sch blackness which the *luna cornua* acquires from the sun's ligh Scheele likewise proved that the variously coloured solar rays in the same degree, and that the chloride of silver is blacke than in any other of the rays. The theory of the decomp light has made but slight progress since these first experimen the enormous development which practical photography has a present day, as regards the chemistry of the photographic pr advance far beyond Scheele's three fundamental discoveries, black powder insoluble in nitric acid, (2) the formation of (3) the specific activity of the violet rays.

The first definite experiments made on the chemical action were those of Priestley. This acute reasoner and active exper *ments and Observations on Different Kinds of Air*, Birminghs is only in presence of light that plants are able to decompose air, assimilating the carbon, and liberating the oxygen, and th mosphere rendered impure by the respiration of animals or by These results were soon afterwards confirmed and enlarged chemists and botanists, amongst others by Ingenhousz, D Ritter, and thus by degrees the grand relations of the atm animal and vegetable life became apparent. It is, however, years that the immediate dependence of all terrestrial life upo been universally admitted. We now know that the animal derives its power from the sun; that it is the rapidly vibrati absorbed by plants and stored up in them, to be given out aga energy, either animal or mechanical, upon the destruction o by oxidation. Only the most rapidly vibrating of the solar to effect chemical change, and hence these violet or most refra the special name of the "chemical rays;" there is, howev between these and the other solar radiations, they all differ onl intensity of vibration.

Measurement of the Chemical action of

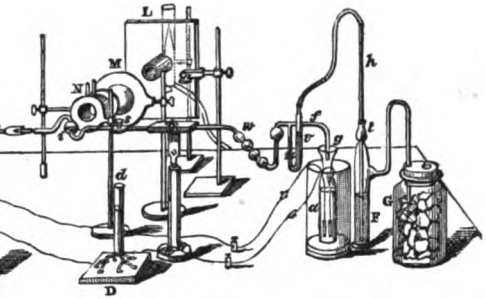
The measurement of the chemical action of light and the which regulate these important actions are subjects which considerable attention. The first person who succeeded in roughly, the chemical action of light was Dr. Draper of New this purpose a reaction originally observed by Gay-Lussac an and hydrogen when mixed in equal volumes, do not combine exposed to diffused light, gradually unite, and even combine an explosion when placed in direct sunlight. Draper const which the quantity of hydrochloric acid formed by the action time could be approximately determined, and although the me was very incomplete, his experiments led him to the first gre

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*action of light varies in direct proportion to the in-
ime of the exposure.* The subject of the measurement
t has been placed upon an exact scientific basis by
Roscoe. For the detailed description of the methods
results which these chemists obtained, we must refer to
Trans. 1857, pp. 355, 381, 601; 1859, p. 879; 1862,
ve a short summary of the principles upon which their
l action of light are founded, and a statement of some of
hich they have been led.

and Hydrogen Chemical Photometer of Bunsen and
nded on the same principle as the photometer of Draper,
xture of chlorine and hydrogen when exposed to light,
strument in being capable of giving accurate and
asmuch as certain necessary conditions for giving
fulfilled. These consist mainly in the perfect unifor-
nstancy of pressure on the gas and liquids throughout
of the disturbing action of radiant heat. This most
represented in *fig.* 702. It consists essentially of three

Fig. 702.



atus in which the sensitive gas is generated by the
; secondly, the apparatus in which the gas is exposed
atus in which the volume of hydrochloric acid produced
mixed gas, consisting of hydrogen and chlorine in equal
hloric acid in the glass vessel *a* containing two carbon
of the Bunsen battery C. By help of the gyrotrope D,
greatly weakened at pleasure, and the evolution of gas
all amount. The mixed gases pass from the vessel *a*
the washing-bulbs *w*, and thence through a horizontal
cock *s*, into the insolation vessel *i*, in which the gases
t. The lower half of this vessel is blackened to protect
From the insolation vessel, the gas passes through the
ovided with a millimetre scale, then through the water
a cylinder filled with slaked lime and charcoal to absorb
allowed to pass through the apparatus, the liquids in
aturated with the gas; but as the saturation goes on
s, and it is only after the gas has continued to pass
that the liquids become perfectly saturated, and the
l volumes of hydrogen and chlorine. During the pro-
emical sensitiveness of the gas increases continually,
equilibrium is attained, the sensitiveness reaches its
atus is ready for use. It retains this same sensitiveness
hort saturation each day previous to the actual observa-
de by closing the stop-cock *s*, and allowing the light to
of the vessel *i*. Combination then occurs, accompanied
ng to the absorption by the water of the hydrochloric
heric pressure forces the water in through the tube *k*
ent of the column of water per minute gives the dimi-
the chemical action effected. The pressure on the gas
essel and measuring-tube, during the observations, is
onstruction of the apparatus; but it is also necessary
nsured in all other parts of the apparatus in the intervals

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between the observations; otherwise the composition of the
altered, and the results will be no longer exact. This unif
sured, by making the gas pass, after the stop-cock *s* is close
m v, containing water, and thence through the tube *h*, which
the vessel E, the pressure being regulated by raising or dep
the caoutchouc mouthpiece *t*. When the stop-cock is open
through the insolation vessel or through the pressure-regul
depth to which the tube *h* is immersed in the water.

To prevent any disturbance from the effects of radiant hea
as a delicate air-thermometer) the light from a coal-gas flam
been condensed by the convex lens M, is made to pass throu
with plate-glass ends, and filled with water. A screen is al
insolation vessel to prevent radiation of heat from the body
together with the screen L, serves to prevent radiation from
found by experiment that the heat evolved by the combinati
not exert any sensible influence upon the results. The whole
a and *l* is connected by ground-glass joints, or by fusion,
organic substance, which could be acted upon by chlorine,
where the waste gas is carried off. The instrument, when th
delicate; the light emitted from a small straight flame of c
placed at a distance of 216 mm. from the insolation vessel, p
sented by the motion of the column of water over nearly 1
one minute. The several indications obtained agree closely
that the instrument gives both accurate and trustworthy r
effected by a coal-gas flame of constant dimensions on differ

Date.	Action in 1 minute.
June 11	14·00
„ 12	14·26
„ 13	13·80
„ 19	13·83
„ 21	13·88
„ 26	13·72
	13·91

Observations made with the constant flame placed at diffe
the insolation vessel, proved that the amount of the chemical
the square of the distance; and experiments made in Septe
same dimensions as used in June, gave results agreeing most c
three months previously.

Photochemical Induction.—When the gas is expos
of hydrochloric acid does not at once attain the maximun
elapses before any alteration of volume is observed; a slig
soon noticed, and this gradually increases until the permane
This remarkable fact was first observed by Draper, who expl
the chlorine, on exposure to light, underwent a permanent
which it possessed more than usually active properties. H
however, shown that neither chlorine nor hydrogen, when se
goes any such modification, no difference indeed being perce
of light on the gases which have been separately insolated
mixture of the same gases evolved, and previously kept in the
therefore, to act by increasing the attraction between the ch
or by overcoming certain resistances which oppose their con
action is termed photochemical induction. The autho
the laws of photochemical induction, and have determined the
the intensity of the light, the mass of the gas, and the duratio
for the results thereby obtained we must, however, refer the rea

The resistance to combination which prevents the union of t
gases until the action is assisted by light, is increased to a
presence of even the minutest trace of foreign gases. Th
hydrogen above that contained in the normal mixture red
to 38. The following table shows the effect of the presen
foreign gases upon the sensitiveness of the mixture. In eac
nation of the pure gases is supposed to be 100.

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lume of chlorine + hydrogen.	Volume of foreign gas.	Ratio of combination of mixture.
1000	0	100·0°
1000	1·3	100·0
1000	10·	60·2
	75·	50·3
	180·	41·3
1000	3·	37·8
1000	5·	9·7
	13·	2·7
1000	6·	55·6

which combination goes on up to a certain point, under to arise, not from any peculiarity in light, but rather chemical attractions themselves. Chemical induction e is nothing but pure chemical action to produce the ation of aqueous bromine be mixed with tartaric acid ic acid is formed, and the rate at which this hydro- uniform, but increases up to a certain point, according is observed in photochemical induction. These pheno- clusion, that the chemical attraction between any two stant amount, but that its action is liable to be modi- to those which affect the conduction of heat or electri- netism in steel. We overcome those resistances when a precipitate by agitation, or a decomposition by inso-

g applications of the law of photochemical induction otography. As an instance of this application, Bunsen ble observations of Becquerel, from which he assumed which can continue but not commence chemical action. enon observed by the French physicist, it is not neces- of a new property of light, as the facts are easily ochemical induction (Phil. Trans. 1857, p. 400). It is Bunsen and Roscoe, that the relations thus proved in ogen occur in a slightly modified form in other photo-

ute Measurement of the Chemical Rays.—The easurement of photochemical actions is the possession of is Bunsen and Roscoe secured by employing a flame of g from a platinum jet of 7 mm. in diameter, and issuing essure very slightly differing from that of the atmosphere. ard flame produces in a given time on the sensitive mix- gen, placed at a given distance, is taken as the arbitrary ion. This action is, however, not that which is directly strument. The true action is obtained only by taking xtinction which the light undergoes in passing through mica-screens placed between the flame and the sensitive made by help of the determinations detailed in the me- n these sources of error are eliminated, it is possible, by o reduce the indications of different instruments to the y, and thus to render them comparable. For this pur- tometric unit for the chemically active rays, as *the amount te by a standard flame placed at a distance of one metre lorine and hydrogen;* and they determine experimentally r of such units which correspond to one division on the ultiplying the observed number of divisions by the num- to one division, the observations are reduced to a com- sed to call this unit a chemical unit of light, and emical degree of light. According to this standard lumination of a surface, that is, the amount of chemically dicularly on the plane surface, can be obtained. It has nce to which two flames of coal-gas and carbonic oxide, f 4·105 c. c. per second, must be removed from a plane n it an amount of chemical action represented by one e of the coal-gas flame, 0·929 metre, in that of carbonic

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oxide, 0·561 metre. The chemical illuminating power, or ch
sources of light, measured by the chemical action effected
distances and in equal times, can also be expressed in terms
these chemical intensities may be compared with the visibl
In like manner, the authors define chemical brightnes
measured photochemically, which falls perpendicularly from
physical point, divided by the apparent magnitude of the su
brightness of circles of zenith-sky of different sizes has been
shows that the chemical brightness of various sized portions
ing 0·00009 of the total heavens, is the same; or, that the
directly proportional to the apparent magnitude of the illum
sky. It is, however, possible to express photochemical actio
an arbitrary standard, but in absolute units of time and space
determining the absolute volume of hydrochloric acid forme
source of light during a given space of time; and in this way
of any surface may be expressed by the height of the col
which the light falling upon that surface would produce, if
mited atmosphere of chlorine and hydrogen. This height, m
and Roscoe call a light-metre. The chemical action of the s
in light-metres, and the mean daily or annual light thus ob
mical climate of a place, and points the way to relations for t
solar rays, which in the thermic actions are already represe
therals, &c.

Chemical Action of Diffuse Daylight.—In order
action exerted by the whole diffuse daylight upon a given poi
the authors were obliged to have recourse to an indirect m
owing to the impossibility of measuring the whole action
sensitive mixture of chlorine and hydrogen. For the purpose
for result, the chemical action proceeding from a portion of sk
magnitude, was determined in absolute measure; and then, b
whose peculiar construction can only be understood by a lon
between the *visible* illuminating power of the same portion
the total heavens was determined. As, in the case of lights
of different degrees of intensity, the *chemical* actions are pr
illuminating effects, it was only necessary, in order to obtain
duced by the total diffuse light, to multiply the chemical act
of sky by the number representing the relation between the
total sky and that of the same zenith-portion. The laws accord
rays are dispersed by the atmosphere can only be ascertained
when the sky is perfectly cloudless. In the determinations
arranged photometer, care was therefore taken that the sli
mist was absent, and the relations between the visible illumi
of sky at the zenith and that of the whole visible heavens,
half hour from sunrise to sunset, the observations being m
hill near Heidelberg, from which the horizon was perfectly fr

The amount of chemical illumination which a point on the
from the whole heavens, depends on the height of the sun ab
the transparency of the atmosphere. If the atmospheric trans
change when the sky is cloudless, a long series of experiments
the true relations of atmospheric extinction for the chemical
the authors, however, believe that the alterations in the trans
cloudless sky are very slight, and they think themselves jus
chemical illumination of the earth's surface on cloudless days
as a function of the sun's zenith-distance. This supposition
ments made on different occasions with varying zenith-dista
as these all agree closely amongst themselves. From a series
June 6, 1858, the relation between the amount of light *optical*
the whole sky, and the amount (taken as unity) which at the
portion of zenith-sky equal to $\frac{1}{1000}$th part of the whole visible
lated for every degree of the sun's zenith-distance from 20°
multiplied by the *chemical* light proceeding from the same por
same zenith-distance, give the chemical action effected by the
amount of chemical light which falls from the zenith-portio
chemical brightness of that portion of sky. This chemical br
by the chlorine and hydrogen photometer on various days an
the sky was perfectly cloudless; thence the authors obtain
expressed in degrees of light, which is effected on the earth'

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$\frac{1}{600}$th part of the whole heavens, under corresponding sun's
90°. The numbers thus obtained have only to be multi-
eries of observations, in order to give the chemical action
ight of day for zenith-distances varying from 20° to 90°.
g between the sun's altitude and the chemical action, the
d during each minute at any given locality at a given
the following places, the amount of chemical illumination
which falls from sunrise to sunset at the vernal equinox is:

.	10,690	Heidelberg . . .	18,220
.	15,020	Naples	20,550
.	16,410	Cairo	21,670
.	18,220		

irect Sunlight.—The chemical action of the direct sun-
wing a small but known portion of direct sunlight to fall
the instrument was placed, so that the insolation vessel
rays thus admitted. By help of Silbermann's heliostat,
during the whole day upon one spot, a small opening of
hutter of a dark room. The fraction of the total sun's
wed to fall upon the chemical photometer was calculated,
was observed: hence the amount of action can be found
oduced if directly shining upon the instrument,—a con-
o fulfil, as the action would become too rapid and the
ttered by explosion.

tion of the sun's action must obviously be cloudless, if
the relation existing between the chemical action and the
g the observations as near sunrise as possible, we find, for
58, one of the days on which such a series of experiments
when the sun's zenith-distance was 76° 30′, the observed
at is, in one minute the column of water moved through
of hydrochloric acid formed, when the sun stood at the
ented by 1·52 division on the scale. Gradually, as the
ion for each minute became larger; until at $9^h\ 14^m$ a.m.,
on the day in question, owing to the formation of clouds,
ions, or was thirteen times as large as at $7^h\ 9^m$. In the
ying table is found the action, expressed in degrees of
observed at the foregoing times, if the whole sunlight had
strument:

Sun's zenith-distance.	Observed action. 1 minute.	Total sun's action in degrees of light.
76° 30′	1·52	5·54
73 49	4·22	15·50
71 37	6·09	22·43
68 34	7·56	27·85
67 30	8·38	38·87
64 42	12·48	45·85
60 48	17·09	62·59
58 11	18·51	67·61

chemical action with the rise of the sun in the heavens
that the solar rays, in passing through the air, are extin-
fact as light; and that as the sun rises higher above the
rough which the rays pass is constantly being lessened:
ect rays reach the earth.

which the direct rays of the sun are thus absorbed in the
experiments, of which the foregoing is only an example:
he sun produces, when at a given height, is known, it is
on which it would produce at any other height.

hemical action of direct sunlight may be thus expressed:
tion effected at a point upon the earth's surface on any
solar rays, depends alone upon the suns's zenith-distance,
lumn of air through which the rays have to pass.

ults agree very closely with the experimental data—with

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the observed action—is seen by comparing the numbers in
observed and calculated action:

TABLE II.

Sun's zenith-distance at time of observation.	Chemical illumination of sun's rect rays at the earth's surface pressed in degrees of light.	
	Observed.	Calculated.
46° 8′	93·0	96·4
50 51	89·2	85·8
57 35	63·1	67·9
58 11	67·6	66·2
60 48	62·6	58·3
64 42	45·9	47·9
67 30	38·9	36·6
68 34	27·9	33·1
71 37	22·4	24·5
73 49	15·5	16·3
76 30	5·5	9·2
Probable error = ± 2·7 degrees of ligh		

Knowing the law which regulates the absorption of the
calculate what the action would be if there were no atmosphe
of the rays. It is thus found that if the sun's rays were no
sage through the atmosphere, they would produce an illumin
degrees of light; or they would effect a combination in one m
atmosphere of chlorine and hydrogen on which they fell per
of hydrochloric acid, 35·3 *metres in height.* The sun's rays h
larly through our atmosphere to the sea's level, effect an a
metres; or three-fifths of their chemical activity has been lo
persion in the atmosphere.

A large number of most interesting conclusions may be dra
noticed. Thus, for instance, we may determine the chemic
rays will produce on the various planets; for we know
chemical illumination varies inversely as the square of the di
the sun. The numbers in Table III. express this chemical a
and in heights of columns of hydrochloric acid called *light-me*
much the sun's chemical action varies on the different plan
receiving so small a portion as to render it impossible that
vegetable life which we here enjoy can there exist.

TABLE III.—*Chemical Action produced by Direct Sunli*

	Mean distances.	Ligh
Mercury	0·387	2
Venus	0·723	
Earth	1·000	
Mars	1·524	
Jupiter	5·203	
Saturn	9·539	
Uranus	19·183	
Neptune	30·040	

Interesting conclusions can be drawn from these facts, conc
the chemical rays on the surface of our earth in different
elevations above the sea's level. The farther removed a situ
the sea, the higher up in the atmosphere it is placed, the g
chemical action which it receives. Thus, in the highlands of
grain flourish at a height of from 12,000 to 14,000 feet, the ch
sunlight is 1½ times as great as in the neighbouring lowland
the same way we can calculate, for any point of the earth's
known, the amount of chemical action which the direct sun
time of day or year. In Table IV. the numbers represent the c
direct sunlight in one minute at the places and hours named, on

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moirs, showing the rise of the action with the progress of s. By comparing the numbers in the table, it is seen how differs at various points on the earth's surface; and we can t the latitude of Cairo, where the chemical action of the great as it is in that of Manchester, the whole flora and al and luxuriant character.

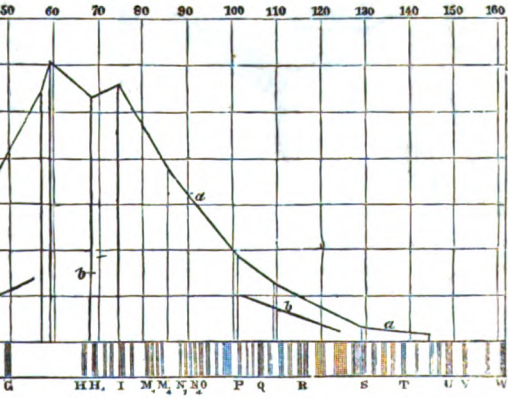
Action effected by Direct Sunlight in One Minute on the Vernal Equinox at

B.	C.	D.	E.	F.	G.
0·0	0·0	0·0	0·0	0·0	0·0
0·02	0·07	0·22	0·38	0·89	1·74
1·53	2·88	5·85	8·02	13·31	20·12
6·62	10·74	18·71	23·99	35·88	50·01
13·27	20·26	32·91	40·94	58·46	78·61
18·60	27·55	43·34	53·19	74·37	98·33
20·60	30·26	47·15	57·62	80·07	105·3

land. E. Heidelberg.
Iceland. F. Naples.
urg. G. Cairo.
r.

Chemical Action of the Constituent parts of the the purpose of measuring the chemical activity of the spectrum (as regards the mixture of chlorine and hydrogen), d the sun's rays through a narrow slit, and then decom- n through two quartz prisms. The spectrum thus produced white screen covered with a solution of quinine, and any measured by a finely-divided scale allowed to fall upon the ometer. For the purpose of identifying the fixed lines in made of a map of those lines made by Professor Stokes. of white light are irregularly absorbed by the atmosphere, l the observations quickly one after the other, so that no e column of air through which the rays passed should occur. ical action effected by various portions of the spectrum on

Fig. 703.



ne particular zenith-distance of the sun. Several maxima spectrum are here noticed.
he indigo, and H in the violet, the greatest amount of action er maximum was found to lie near I in the ultra-violet rays. d end of the spectrum, the action became imperceptible maximum of visible illumination); but towards the other tion was found to extend as far as Stokes's line U, or to a I greater than the total length of the ordinary visible

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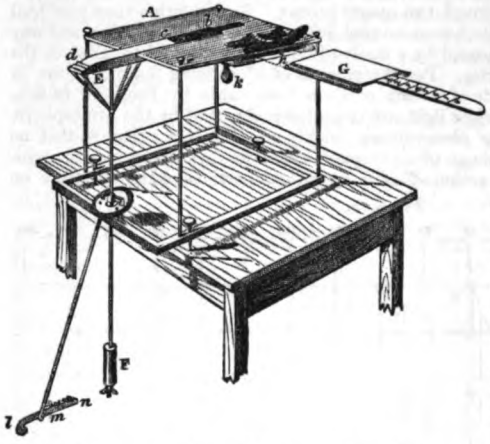
We must, however, remember that the curve which represents t position effected by the chemically active rays, varies according substance acted upon; thus Sir John Herschel showed (Phil. Tran iodide of silver washed with nitrate was decomposed by ultra-viole no action whatever upon the chloride of silver; and whereas, in th the action extends but a little beyond the line E, the action in the c visible to the very extremity of the visible red rays, and the ma bromide lies in the indigo rays, that of the iodide lying in the la the lines I and M. (See also Becquerel's results, p. 632; a *de Physique*, iv. 226.)

Chemical Photometer adapted to the purposes o Registration.—Having thus ascertained the chief laws regulatin of light, and the distribution of direct and diffuse sunlight upo when the sky is unclouded, Professors Bunsen and Roscoe proceede of measuring applicable to the direct determination of the total ef varying cloud and sunshine of our changing climate. The object gation (Phil. Trans. 1863, p. 139) has been to invent a trustworth the daily variation in the sun's chemical intensity, which shall be of practice as to be applicable to regular meteorological registrati

Although many fruitless attempts have been made to constru comparison of the blackness produced by sunlight upon photogr and Roscoe found that the desired end could be obtained in this certain essential conditions.

For this purpose it was necessary to construct an apparatus in sensitive paper could be exposed to sunlight for definite times mea tions of strument, photom in *fig.* 70

Fig. 704.



An iro metal pla placed ho set-screws straight broad an long, is c which is drawing, and elasti blackened to *c*, and curved d the pendu pendulum brate, the rolls on drum E a covers an slit, so throughou

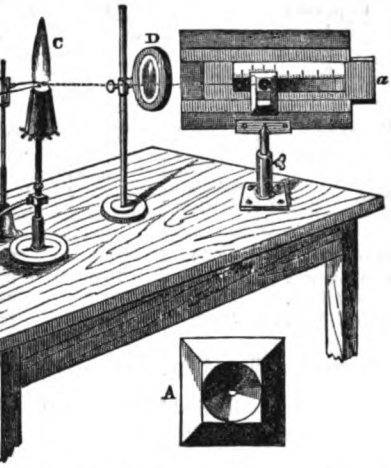
of the slit is exposed for a different period. If we wish to use thi purpose of exposing a photographic surface to the action of the times, the paper is gummed upon the white surface of the metallic this is then covered by a metallic lid, which does not touch the p arrangement pushed into the dark groove *h*, placed directly u protected from the entrance of light by a lappet of cloth, which ha metallic lid is then withdrawn, the screw *k* turned, and thus the pap against the slit, so that no light can enter sideways between the metallic edges of the slit. By raising the lever *n m l* at *l*, the pe from the catch at *m*, and, after completing a vibration, it is held fa at *n*. If it be required to double or to multiply the time of in necessary to repeat the vibration, once or several times, care being vibration to raise the rod of the pendulum so as to allow the end t catch. In order thus to set the pendulum in motion, and to stop it ease, the lever is once for all balanced by a small weight at *l*, so t but slightly heavier than the arm *l*.

Before this instrument can be used for measuring the chemical necessary—

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ting between the several tints and the intensity of the
tints.
per which shall always possess the same degree of sensi-
pared when required.
ries of experiments, that it was possible, by adhering
manipulation, to prepare standard papers which, when
e of sensitiveness; so that if the same light falls upon
loured to the same tint.
d that the tint attained by such a paper was constant
ng upon it also remained constant; so that light of the
aper for the time 1, produced the same blackening effect
ng upon it for the time 50.
gulates the degree of shade of the paper, and having a
degree of sensitiveness, it is easy to obtain absolute
action of light. For this purpose, an arbitrary unit of
xing a standard tint or paint which can be easily and
.
shall, in a second, or the unit of time, produce a blacken-
ographic paper equal to that of the standard tint, is said
1. If the time needed to produce this same tint is
pendulum-photometer to be 2 seconds, then the chemical
.
to obtain accurate measurements of the chemical action
nt, is to be able to find the time necessary to effect a
r equal in shade to the standard tint. This is done by
nade in the pendulum-photometer.
y comparing these tints, the ordinary daylight, or even
a change would thereby be produced on the sensitive
t act chemically must be used; such a light is the mono-
ght from this flame possesses another advantage, namely,
es of colour are not seen; variation in *shade* alone being
t for thus reading off the point having a shade equal to
een in *fig.* 705. A millimetre scale, similar to the one
a wooden board, *a* (*fig.* 705), covered with paper, and
a fixed wooden stand. The strip of photographically

Figs. 705 and 706.



om the slide G and gummed upon the board *a*, so that it
to the scale on the board as it had to the scale on the
small square wooden block having a circular hole in the
r, the lower half being covered by the paper of which the
rmined. This block is pressed by means of a spring, as
osition against the strip of paper. On throwing the image

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of the soda-flame C, by help of the convex lens D, upon the block, it is easy, by drawing the slide backwards and forward point at which the upper and lower halves of the circular h It is then only necessary to read off on the scale the numb which the paper at that point has been insolated, in order to shade which the paper in that time has attained. To ensure tions, it is necessary that the eye should always be placed in o most advantageously in a direction nearly perpendicular to paper.

By help of this soda-flame, the coincidence of shade of the standard tint can be read off with the greatest precision. possibility of preparing a constant sensitive paper, is seen by tables, extracted from the detailed paper printed in the Phil 1863, to which we must refer for positive proof of the delica the method.

Papers variously prepared were exposed for the same time Each reading is the mean of several observations; identi identity in the shade, and, therefore, the constant sensitivene

The standard paper is prepared by soaking photographic pa mon salt of given strength (3 to 100), and then allowing it to silver solution (12 nitrate of silver to 100 of water). When th tion varies, the sensitiveness of the paper alters very rapidly. of the silver-bath produces, on the contrary, but little change paper.

Different qualities of paper and alterations of atmospheric do not affect the sensitiveness of the paper.

1. *Effect of altering the Strength of the Silver-bath. Pap containing* 3 *pts. Chloride of sodium to* 100 o

Nitrate of silver to 100 of water.	Observer A.	Reading
12	128·6	. .
10	128·7	. .
8	128·7	. .
6	129·7	. .

2. *Effect of altering the Strength of the Salt*

NaCl to 100 of water.	Observer A.	Reading
1	2·6	. .
2	95·7	. .
3	132·6	. .
4	167·0	. .

3. *Experiment showing the constant Sensitiveness of t*

Paper.	NaCl to 100 of water.	Intensity No. 1.	
		Observer A.	Observer B.
Upper part of sheet 2	2·950	70·2	70·0
Lower part of sheet 2	3·026	70·6	69·3
Middle of sheet 1 .	3·026	70·0	69·5
Middle of sheet 3 .	3·000	70·0	70·4

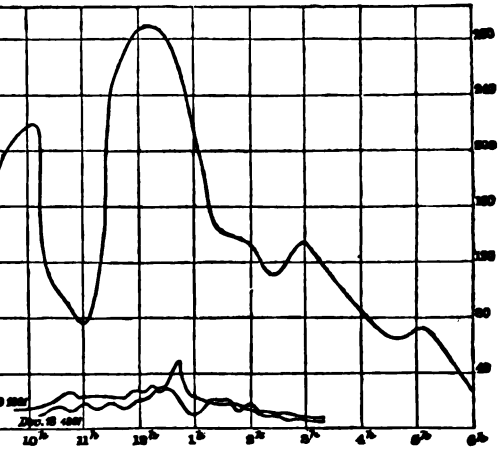
All these papers were silvered in a solution containing 12 100 of water.

In order to measure the chemical intensity of the daylig needed is to expose a strip of standard paper in the pendulu number of vibrations, and then to find upon the strip thus ex a shade equal to the standard tint has been produced. Refe time of exposure necessary to produce this tint, and the rec sents the intensity of the acting light. If the time nec chemical intensity would be $\frac{1}{2}$; if the time were $\frac{1}{2}$ second, In this way curves of daily chemical intensity are made, caused by clouds, or by the changing altitude of the sun. T and minima exactly corresponding to the appearance and

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rence between the sun's chemical intensity in summer and ference to the curves on *fig.* 707.

Fig. 707.



es of the pendulum-photometer, a much simpler method of s has been arranged, as follows. A graduated strip made er is fixed in hyposulphite of sodium, and pasted upon a cale. The shades of certain points on this fixed strip are on given points upon a graduated strip prepared in the usual sulphite. The fixed strip is thus calibrated in terms of the it may then be used as a means of measuring the chemical ces of the standard paper are then exposed for a given time ired to measure, until the shade approaches that of a part of of exact coincidence is then read off by the soda flame as e of standard paper of 1 square inch of area will serve for , and the whole arrangement for exposure may be carried in the chemical intensity of day- and sun-light in Manchester, ument on more than 40 separate days of the year 1864, fully d ease with which these measurements can be made, and the induces the writer of this article to express a hope that ents may be introduced into meteorological observatories.

various Points on the Sun's Surface.—The determination of f the various portions of the sun's disc is an interesting thod of photometric measurements.

aced on a 3-inch refractor, the writer allowed the image of in diameter—to fall upon the standard paper. The sun- ents interesting features: in the first place, the chemical in- ions are 3–5 times as great as that of the portions on the s kind, in the case of the luminous and calorific rays, has astronomers, and it is doubtless caused by the absorption sphere.

re obtained by measuring the chemical brightness at various n May 9, 1863; from these numbers it will be seen that the very irregularly.

EMICAL BRIGHTNESS OF SUN'S DISC.

2. 15° from edge of sun's disc.			3. At the edge of sun's disc.		
N. Pole.	Equator.	S. Pole.	N. Pole.	Equator.	S. Pole.
38·8	48·4	58·1	18·7	30·2	28·2
52·8	—	56·6	30·5	—	41·0

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Bright patches of considerable area were seen on the pict
were not caused by irregularity in the paper or in the len
the presence of clouds in the luminous atmosphere of the su
have some intimate connection with the well-known phenom
seen during the solar eclipse.

Optical and Chemical Extinction of the Chem
determine whether the act of photochemical combination (i
hydrogen) necessitates the production of a certain amoun
which an equivalent quantity of light is expended, or whet
pendent upon a restoration of equilibrium effected without a
loss of light, Bunsen and Roscoe have studied the phenomen
surfaces, and in the interior of a medium exposed to the che

When light passes through any medium, part of it is lost
another portion by absorption within the medium, so that
light is only a fraction of the incident light. This is t
with the luminous rays, and Bunsen and Roscoe have
of absorption and reflection of the chemical rays for gla
passing light from a constant source, through cylinders with
dry chlorine, they found that, with a given length of cylind
rays transmitted, when no chemical action takes place, is
dent light in a constant ratio; or in other words, the absorp
proportional to the intensity of the light. They also foun
chemical rays transmitted varies proportionally to the densi
If, however, the light passes through a medium in which it
also excites chemical action, it is found that, in addition to
ready spoken of, a quantity of light is lost proportional t
action produced. Thus the depth of pure chlorine gas at
through which the light of a coal-gas flame must pass in
is found to be 173·3 mm.: hence, since the quantity of lig
density, the depth of chlorine diluted with an equal volume
ing and chemically inactive gas required to produce an exti
mm. But when the sensitive mixture of equal volumes of
used, the depth of the mixture to which the light must pene
to $\frac{1}{10}$ is found only to be 234 mm. Hence Bunsen and Ro
in this case absorbed in doing chemical work.

Light from other sources gives results similar in chara
amount. Diffuse light of morning reflected from the zenith
to $\frac{1}{10}$ by passing through 45·6 mm. of chlorine, and through 73
ture; diffuse light is reduced to $\frac{1}{10}$ by passing through 19·7 m
57·4 mm. of the sensitive mixture. Hence it appears that
morning light are absorbed by chlorine much more quickly
and those of evening light with still greater facility. From
the chemical rays reflected at different times and hours, pos
but also qualitative differences, similar to the various colour
trum. Photographers are well aware of this qualitative diff
know that the amount of light photometrically estimated giv
chemical activity; they prefer a less intense morning light
for taking pictures.

Photographic Transparency, or Diactinic Power of differe
been mentioned (p. 632), that the chemical rays of the spectr
degrees by different media. On this subject, some important e
made by Professor W. A. Miller (Phil. Trans. 1863, p. 1
The mode of observation consisted in refracting the rays wh
parent medium, through a prism and lens of quartz, and r
of collodion coated with iodide of silver (p. 693), whereby
chemical spectrum was obtained. The light employed was
from an induction-coil between two metallic wires, general
peculiarly rich in chemical rays, yielding a chemical spect
times the length of the visible spectrum. The following are
results obtained:

1. Colourless solids which are equally transparent to the
in permeability to the chemical rays.—2. Bodies which are
rent in the solid form, preserve their transparency in the li
3. Colourless transparent solids which absorb the chem
absorptive action in the liquid and gaseous states.—4. Pur

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ompounds which cannot be obtained in the solid form
uch experiments, may be subjected to trial in aqueous

t the photographic transparency of a few of the various
ours subjected to experiment:—

Transparency or Diactinic Power of

Liquids, 0·75 in.		*Gases and Vapours.*	
Water	74	Oxygen	74
Alcohol	63	Nitrogen	74
Dutch liquid	36	Hydrogen	74
Chloroform	26	Carbonic anhydride	74
Benzene	21	Ethylene	66
Methylic alcohol	20	Marsh-gas	63
Amylic alcohol	20	Hydrochloric acid	55
Oxalic ether	19	Coal-gas	37
Glycerin	18	Benzene vapour	35
Ether	16	Hydrobromic acid	23
Acetic acid	16	Hydriodic acid	15
Oil of turpentine	8	Sulphurous anhydride	14
Sulphide of carbon	6	Sulphydric acid	14
Trichloride of arsenic	5	Air, 0·1 in. pressure	74

tained upon the collodion plate commenced in each case
rum, corresponding with a spot a little more refrangible
e line H 100, and numbering backwards for the less
ing at 84, the commencement of the photograph in each
e limit of the most refrangible rays at 170·5.
s almost always exerted upon the most refrangible rays;
gases and vapours, chlorine, bromine, and iodine,
e general rule, and is by no means proportional to the
chlorine, with its yellowish-green colour, cuts off the
xtremity through fully two-thirds of the spectrum; the
off about one-sixth of the length of the spectrum, the
to the less refrangible extremity, whilst the deep violet
less refrangible rays to pass freely for the first fourth of
rable absorption occurs, and afterwards a feeble renewal
xhibited towards the more refrangible end.
unds submitted to examination, the fluorides were
most transparent; then follow the chlorides of the
ne earth-metals; the bromides are less diactinic,
g diminution in this respect. The group most remark-
is that of the nitrates. Nitric acid, whether simply
ned with bases, has a specific power in arresting the
angible portion it transmits freely, but intercepts the
e points, whatever salt be employed, provided the base
s are remarkably diactinic.
yers, absorbs the whole of the more refrangible chemical
r that lenses of quartz, or of water enclosed in quartz,
of glass for the use of the photographer. This, however,
very transparent to the less refrangible portion of the
nd the violet end of the visible spectrum to a distance as
e red end of the spectrum is below it; and these rays are
and powerful chemical rays in the solar spectrum, which
ngibility much beyond this point; whereas in the elec-
le rays predominate.
diactinic acids, usually furnish diactinic salts; but such
e of the silicates are as diactinic as silica itself in the
ydrogen is eminently diactinic; and iodine-vapour,
colour, is also largely diactinic, but hydriodic acid
er of them.
t appear to act more energetically as absorbents than

p. 606), by receiving the invisible rays upon a fluorescent
ble alkaloïds and the glucosides are, almost without

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exception, intensely opaque for a portion of the invisible r
energy comparable, for the most part, to that with whic
indigo or madder, absorb the visible rays. The mode of
highly characteristic of each compound, and frequently
body, according as it is examined in an acid or an alkalin
The quality of the rays *reflected* from polished surfac
cannot be predicted from the degree of luminosity of t
though not the most brilliant of the metals, reflect the ch
than the brilliant white surfaces of silver and speculum-m
of Chemistry, 3rd ed. vol. ii. p. 899.)

Influence of Light upon Pla

The important effects produced by sun-light on livi
noticed. Many experiments have been made for the purp
which the different portions of solar light effect upon pla
their growth. The subject is an extremely complicated on
experimenters differ widely. Thus, for instance, whilst Pa
rays are those which especially determine the growth
Draper state, as the result of their experiments, that the y
are those which act most powerfully in decomposing th
Mr. Robert Hunt* draws the following conclusions fro
subject:

1. The luminous rays prevent the germination of seeds.
2. The chemically active rays quicken germination.
3. Light acts to effect the decomposition of carbonic aci
4. The luminous and chemical rays are essential to th
matter of leaves.
5. The luminous and chemical rays, independent of th
development of the reproductive organs of plants.
6. The heat-radiations corresponding with the extrem
facilitate the flowering of plants and the perfecting of thei

Photography.

The first well-authenticated attempts to produce pictur
action of sun-light were made by Thomas Wedgwo
the year 1802;† but it would appear probable from recen
ton and Watt actually obtained sun-pictures at the S
year 1799. No written statement of the method employ
however, as yet been found, and we must therefore still giv
the credit of having first described a mode of obtaining p
light. The method adopted by Wedgwood was that of
leather with a solution of nitrate of silver. By this means h
on glass, and took profiles, and Davy even succeeded in
seen in the solar microscope; but neither of these chem
unshaded portions of the picture from being coloured by e
the year 1814 M. Niépce examined the action of light o
with the object of obtaining an unalterable image in the c
to a certain extent, inasmuch as the light rendered the res
vents, so that, by the subsequent action of an acid on the
parts upon which the light had not fallen were etched. In 1
an account of his experiments to the Royal Society, and i
M. Daguerre, who had been previously but unsuccessfully
of the particulars of his process. The two investigators
common, proposing many different modes of producing the
they were termed, without great success, until the death o
continuing his experiments after this event with the s
enough to discover, in 1839, the method which bears his
and pension offered by the French government for the dis
manently fixing the image formed in the camera. The p
essentially in allowing the vapour of iodine to act upon a p
thus becomes coated with a thin film of iodide of silver; t

* See Report by Robert Hunt "*On the present state of our know*
Solar Radiation." Brit. Assoc. Reports for 1850.
† Journal of Royal Institution, June 1802.

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e camera, so arranged that the image of the object to be
rface, which thereby undergoes a change, not however
ate from the camera. In order to develop the latent
o the action of the vapour of mercury, which produces
ts of the plate, according as the iodide has been more or
e light. The undecomposed iodide was then dissolved
solution of hyposulphite of sodium, and the picture was
nce Daguerre's time, this process has undergone con-
gst these, we may mention the exposure of the plate to
h the sensitiveness of the film is greatly increased, and
pon the surface of the film during the process of fixing,
f the picture are rendered more effective. For the details
, we must refer the reader to photographic text-books.
e chemical change effected by the light on the iodo-
erstood, but it is evidently analogous to the change
mixture of chlorine and hydrogen before combination
photochemical induction, the film being so modified as
nposition when brought into contact with the vapour of
s produced varies in thickness according to the in-
on of the light, and different shades are therefore seen,
reflected light, corresponding to the lights and shades of

n of sun-pictures on paper attracted but little attention
until the year 1839, when Mr. Fox Talbot published
g." This consisted in exposing in the camera a paper
ommon salt, and afterwards washed over with a strong
he image thus obtained was a negative one, the light
ght, and the pictures were fixed by immersion in a solu

en made in this process. In 1841 Fox Talbot patented
s the "Talbotype or Calotype process," in which the
silver by dipping it first in nitrate of silver, then in
us prepared is not sensitive *per se* to the action of light,
shing it over with a mixture of nitrate of silver and
exposed to the camera for two or three minutes, it does
less the light has been very strong); but still the com
n change by the influence of the light: for, on subse
he mixture of aceto-nitrate of silver and gallic acid,
ative image comes out on it with great distinctness.
the paper with hyposulphite of sodium, which removes
er not acted upon by the light, and thus protects the
exposure to light. The negative picture thus obtained
cing it between two sheets of blotting-paper saturated
moderately heated smoothing-iron over the whole. It
ositive pictures, by laying it on a sheet of paper prepared
, and exposing it to the sun.

e progress of photography is the substitution, by Mr.
of iodised collodion spread upon glass for the iodised
ss, to receive the negative image in the camera.
o much more certain and rapid, and the positive pic-
the negative by printing on paper are found to be so
when the transference occurs through paper, as in the
ethod is now universally employed. In this process, as
ge produced in the camera is a latent one, and requires
uch as pyrogallic acid, or protosulphate of iron, which,
xygen, induces, in presence of nitrate of silver, the re-
de to the metallic state. For a description of the best
used in the Collodion method, the reader may consult
graphic Chemistry."

tallic salts besides the salts of silver are acted upon by
tions of many of these salts have been specially studied
il. Trans. 1840), in his celebrated Memoir "On the
the Solar Spectrum;" and, founded upon these different
producing pictures have been described, all of which are
ll description of these methods, we may refer the reader
ht."

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Nature of the Chemical Change effected by Light on Silver Salts.—Although the exac chemical decomposition effected by light on the chloride, bromide, and iodide of silve has long been a subject of experimental discussion, still much remains to be learn concerning the composition of the photographic image. The general result of investig tions upon this subject may be stated to be that, in the first place, a sub-salt of silve of a grey or violet colour is formed, whilst by a further action of the light the silver i probably reduced to the metallic state. It appears, however,* most difficult to prepar the sub-salts of silver in a pure state, either by the action of light, or by other chemic methods, the evidence of the presence of such a salt in the violet-coloured chlorid depending upon the well-known fact that this substance is unacted upon by nitri acid, but decomposed by ammonia into chloride and metal. The recent experiments o Vogel (Pogg. Ann. cxvi. 497) confirm this result, as he shows that when pure and dr chloride and bromide of silver are insolated, chlorine and bromine are liberated, an a substance insoluble in nitric acid, in each case, produced: he was unable to dete free iodine when pure iodide of silver is exposed to light, and hence he concludes th this salt is not decomposed by light. Vogel has likewise observed that the result obtained when the above-mentioned salts are prepared with an excess of silver-sal instead of an excess of the precipitant, are somewhat different: thus, whilst the iodid prepared with excess of iodide of potassium shows no change of colour, that prepare with excess of silver becomes decidedly grey on exposure to light.

A singular effect produced by the red rays upon a blackened silvered paper wa observed long ago by Ritter, and confirmed by Herschel. If prepared paper soaked i nitrate of silver solution be blackened by exposure to light, and then submitted to th action of the solar spectrum, those portions upon which the violet rays fall becom darker, whilst those exposed to the red rays become lighter, and assume a brick-re colour; hence it would appear that the least refrangible rays exert opposite action upon the sensitive silver-salts. Claudet has also shown (Phil. Trans. 1847) that ex posure to the red rays neutralises the effect previously produced on a sensitise daguerreotype plate by white light.

We are as yet quite unacquainted with the essential nature of the change brough about by the action of light. Thus, we do not know whether, in the blackening c chloride of silver, the light used up in the decomposition is equivalent to the wor done, as in the case of the decomposition of water by the galvanic current where th force needed to separate the molecules of oxygen and hydrogen is as large as tha evolved by the combinations of the gases; or, whether the chemical actions of light re semble that sudden splitting up which occurs in certain compounds (the chlorid of nitrogen, for example) where they are placed in circumstances under which the can no longer exist, and where the force establishing the change bears no equivalent rela tion to the forces developed in the resulting decomposition.

Chromo-photography.—Many attempts have been made to reproduce in the photo graph the colours of natural bodies; and although these attempts have not succeede to the full extent of fixing the coloured picture, yet a certain degree of progress in th production of tinted images has been made. Thus, for instance, Becquerel (Ann Ch. Phys. [3] xlii. 81) has described a method by which a coloured image of the sola spectrum can be prepared, as well as representations of the coloured rings formed i crystals by polarised light. In order to obtain these coloured images, a polished plat of silver is immersed in dilute hydrochloric acid, and a film of sub-chloride forme upon the silver by allowing the plate to form the positive electrode of a Bunsen's bat tery The plate thus prepared becomes variously tinted when exposed to the sola spectrum, some of the rays being reproduced with their distinctive colours, whils others either produce no effect or give rise to tints differing from their own. Othe experimenters, especially Niépce de St. Victor and Campbell, have obtaine somewhat analogous results; but, as yet, the coloured images produced by these an similar processes have resisted all attempts to render them permanent.

Photographic Engraving, Lithography, and Galvanography.—Th original photographic process proposed in 1827 by Niépce has been lately modifie by M. Niépce de St. Victor, for the production of photographic engraving on steel A plate of steel is covered with a layer of prepared bitumen, and being placed under an ordinary positive photograph, is exposed to light; on treating the bitumen with naphtha and benzol, those portions which have not been insolated dissolve, leaving the steel plate exposed for the subsequent action of acid. The plate thus prepared is then sub mitted to the usual processes employed in aqua-tint engraving. A somewhat similar process was patented by Mr. Fox Talbot, in 1858, for etching by chemical means a positive photograph on a copper plate. This method has recently been modified

* See Report on the Nature of the Photographic Image, Brit. Assoc. Reports, 1859, p. 106.

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Sir H. James and Mr. Osborne of Melbourne, to the d zincographs from photographs. Mr. Osborne's process f paper with a solution of acid chromate of potassium in pared paper to light by placing a negative photograph exposure, the paper is placed in water; the unchanged d away, and those parts which have been acted upon by the then coated with lithographic ink, and transferred to the e; the prints, obtained by transfer in the usual way, are e.

ography, founded on the decomposition of gelatin and has likewise been proposed. The action of light on this the gelatin, rendered evident on immersing the plate in l of the various parts. A mould of this raised picture is nd a copper plate is made from the gutta-percha mould this plate is again copied by electrolysis, and from this nts are struck off. This process gives the means of multiplications of the same subject, but the impressions

H. E. R.

LLULOSE (i. 818).

1032) and FUEL (ii. 721).

—A brown substance obtained by Reichel (*Ueber che Bestandtheile*, Leipzig, 1856) from old Huanoco cin- ined by Hesse (Ann. Ch. Pharm. cix. 341). It is very s; the solution does not absorb oxygen from the air at brown substance, boiled with caustic potash, gives off then remaining in solution appears to have the composi- uinova-red and phlobaphene, and resembling a substance cinchona-bark. Hesse is of opinion that a brown humus- he composition $C^{20}H^{20}O^8$, and essentially different from 9), is deposited in the barks of cinchona and other allied

. These names were applied to a volatile liquid of vari- t about 60°, obtained from crude wood-spirit by treatment subsequent rectification. Völckel (Pogg. Ann. lxxxiii. mposition $C^8H^{12}O^2$; but the analyses made of it by other nd Schweizer, Liebig, Kane, and L. Gmelin, exhibit tage of carbon differing by about 10 per cent.), and Dancer a more careful investigation of crude wood-spirit, has variable proportions, of methylic alcohol, acetone, acetate l, $C^4H^{10}O^2 = \frac{(C^2H^4)''}{(CH^3)_2}O^2$, and that the supposed lignone

(See METHYL-ACETAL and METHYL-ALCOHOL.)

UM.

having the angles and character of sphene (Dufrenoy), Apennines.

next article.

ARE. *Privet.*—The *ripe berries* of this plant contain, arm. [3] xxxv. 328), a crimson colouring matter, ligulin, l, either pure or etherised, but insoluble in ether. It does composed by 48 hours' boiling with pure water, is coloured ommends this reaction for detecting acid carbonate of ed again by acids. It has not been obtained pure.

, according to Polex (Arch. Pharm. [2] xvii. 75), a tract, called ligustrin, insoluble in ether and in abso- ter and in dilute alcohol, forming solutions which do not y metallic salts. Strong sulphuric acid gives, with ligus- r, changing on dilution to a cornflower-blue or violet. ivet contain mannite. (Polex, *loc. cit.* Kromayer,

iron from Przibram in Bohemia, having the appearance , and probably a product of the decomposition of iron ous, earthy substance of blackish-green colour, and in fine t with leek-green colour under the microscope. Hardness

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– about 2. Specific gravity = 3·043. A specimen, as pure as could b
often mixed with iron pyrites and ferric hydrate), gave, by analysis, 32·48
and oxygen, and 10·20 water (= 94·20, including 1·96 carbonate of calciu
pyrites), agreeing approximately with the formula ($2FeO.3SiO^2.H^2O$).(

LIMACIN. A substance obtained by Braconnot (Ann. Ch. P
from the garden-snail (*Limax agrestis*). When dry it forms a white ea
crumbled between the fingers. It is somewhat soluble in cold, more s
water, soluble in boiling alcohol, in concentrated hydrochloric acid, an
line liquors. The solution in cold water is precipitated by tannic acid
limate, neutral lead-acetate, ferrous sulphate, and the acetates of copper
but not by oxalate of ammonium. By dry distillation it yields carb
nium, and leaves charcoal with a small quantity of alkaline ash.

LIMAX. According to A. Vogel and C. Reischauer (N. Jahrb.
many coloured snails of the genus *Limax* contain a colouring matter
violet in dilute acid solution, brown or black in more concentrated
obtained by macerating the animals, freed from their viscera, with di
and precipitating the solution with ammonia. The brown or black iri
tate is insoluble in water and in alcohol. The nitric acid solution gra
a crimson colour, then becomes colourless. The colouring matter, when
a large quantity of phosphate of calcium.

LIMBERLITE. Syn. with Chrysolite (i. 958).

LIME. Oxide of calcium (see Calcium, i. 718).

LIME, CHLORIDE OF. See Chlorine (i. 904, 908) and
(iii. 237).

LIME, OIL OF. $C^{10}H^{16}$.—The volatile oil of *Citrus Limetta*, obt
ling the torn and pressed rinds with water (i. 1003).

LIME-FLOWER, OIL OF. A volatile oil, obtained from the
europæa, by distillation with water (Brossat, J. Pharm. vi. 396), or
with ether in a percolator. The amount does not exceed 0·1 per cent.
than water, very volatile, and has a strong odour of lime-flowers. (G

LIMESTONE. The generic name of all rocks having carbonate
their principal constituent. The principal accessory constituents are
1. Silica and alumina. The former occurs in crystalline limestones,
crystalline quartz; in compact limestones, sometimes as sand in small
frequently combined with alumina, in the form of clay. Nearly all lim
small quantities of clay, and in some the quantity amounts to several
the limestone then passing into marl. Limestones also occur contai
calcium, as at Gjellebäk in South Norway.—2. Iron: sometimes as ferr
times as ferrous carbonate; generally only in small quantities and trace
nese: either as manganic oxide or as manganous carbonate. In still s
than the iron, and often absent altogether.—4. Magnesia, as carbonate:
accessory constituent of limestones, but in true limestones not exceed
per cent. When the proportion is larger, the limestone passes into d
stone and dolomite.—5. Phosphoric acid: appears to occur only occas
very inconsiderable quantity, no limestone having yet been found to
than 0·2 per cent. of it.—6. Alkalis, namely potash and soda, have be
considerable number of limestones by Schramm (J. pr. Chem. x
Fehling (*ibid.* 446). Schramm found from 0·1 to 0·3 per cent. alkali
part as carbonate, in smaller quantity as chloride. Fehling obtained f
limestones about 3 per cent. alkaline carbonate. According to Schram
occurs in larger quantity than potash, about in the ratio of 2 at. soda to
7. Organic (bituminous) matter, probably in all limestones, excepting
line ones; sometimes in mere traces, sometimes in more considerable q
anthraconite, stinkstone, and bituminous limestone, the presence of or
very conspicuous.

The following enumeration of the sub-species and varieties of lime
from *Ure's Dictionary of Chemistry*, and originally from *Jameson's Min*

1. Foliated limestone; of which there are two kinds—*calcspa*
granular limestone. The first will be found in its alphabetical place in t

Granular foliated limestone.—Colour white, of various shades, some
massive, and in distinct angulo-granular concretions; lustre gliste
pearly and vitreous; fracture foliated; translucent; hard as calcspar; b
gravity (of Carrara marble) 2·717. It generally phosphoresces when pou
thrown on glowing coals; infusible; effervesces with acids. It is a pu

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ranite, gneiss, &c., and rarely in secondary rocks; it is primitive rocks in Europe, and affords the finest marbles. e, the Marmo Greco, the white marble of Luni, of Car- the translucent white marble of statuaries, and flexible the white marbles which the ancients used for sculpture ique marble, *Rosso antico* of the Italians, and Egyptian *ico*, an indeterminate mixture of white marble and green rble; the antique Cipolin marble, marked with green- or chlorite; and African breccia marble, are the prin- ncients. The Scottish marbles are—the red and white ntains hornblende, sahlite, mica, and green earth; the t others, consisting of limestone and tremolite, or occa- marble; the Assynt in Sutherland, introduced into com- shead: it is white and grey, of various shades. The lish; the Boyne; the Blairgowrie; and the Glenavon. anular foliated limestone have been quarried in England. e *Verde antico*. The black marbles of Ireland, now so re lucullites. The Toreen, in the county of Waterford, a grey marble, beautifully clouded with white, has been same county. At Loughlougher, in Tipperary, a fine county of Kerry affords several variegated marbles. Of ous account is given by Professor Jameson, *Mineralogy*,

of which there are three kinds—*common compact lime-* and *roestone*.

e has usually a grey colour, with coloured delineations. ious extraneous shapes; dull; fracture fine splintery; ter than the preceding sub-species; easily frangible; gravity 2·6 to 2·7. It effervesces with acids, and burns ate of calcium, with variable and generally minute pro- n, magnesia, and manganese. It occurs principally in ith sandstone, gypsum, and coal. Many animal petri- re found in it. It is rich in ores of lead and zinc, the tal being situated in limestone. When it is so hard as as a marble, under the name of shell, or *lumaccella* dstone and coal formations, both in Scotland and Eng- y abundant mineral in all the districts where clay-slate Florentine marble, or *ruin marble*, is a compact lime- s of this stone resemble drawings done in bistre.

. Colour dark bluish-grey, partly veined with white; e; fracture fine earthy; opaque; streak white: semi- vy. Its constituents are, lime 58, carbonic acid 28·5, 1, magnesia 0·5, oxide of iron 0·25, carbon 0·25, and is found in loose masses among unaltered ejected of Vesuvius. In mosaic work, it is used for represent-

and grey; massive, and in distinct concretions, which ue; fracture of the mass round granular; approaching 2·6 to 2·68. It dissolves with effervescence in acids. It and lias limestone. In England this rock is called Bath- one, and Oolite. It extends, with but little interruption, hks of the Humber in Lincolnshire. It is used in apt to moulder away, as is seen in the ornamented work

(i. 845).

ck-milk. Colour white; in crusts or tuberose pieces; rticles; soils strongly; feels meagre; adheres slightly to rnatant. It dissolves in hydrochloric acid with effer- e of calcium. It is found on the north side of Oxford, vell, and near Chipping Norton: as also in the fissures nent. It is formed by the attrition of water on lime-

f which there are two kinds—satin-spar, or the common *Satin-spar*. White of various shades; massive, and ; lustre glistening and pearly; fragments splintery;

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feebly translucent; as hard as calcareous spar; easily f
Its constituents are, lime 50·8, carbonic acid, 47·6? St
quantities of gypsum. It occurs in thin layers in clay-
berland; in layers and veins in the middle district of S
sometimes cut into necklaces, &c.

Fibrous calc-sinter. Used as marble; the ancients f
the *alabaster-box* of Scripture. See CALC-SINTER (i. 720

6. Tufaceous limestone, or Calc-tuff. Colour
shapes; enclosing leaves, bones, shells, &c.; dull; fractur
soft; feels rough; brittle. It is pure carbonate of
generally in the neighbourhood of rivers; near Starly
places. Used for lime.

7. Pisiform limestone, or Peastone. Colour
in distinct concretions, which are round granular, comp
thin and concentric lamellar. In the centre there is a b
of some mineral matter; dull; fracture even; opaque;
2·532. It is carbonate of calcium. It is found in gr
Carlsbad in Bohemia.

8. Slate-spar; *Schieferspath.* Colour white of va
distinct curved lamellar concretions; lustre glistening ar
soft; between sectile and brittle; feels rather greasy; sp
tuents are, carbonate of calcium, with three per cent. of
in primitive limestone, in metalliferous beds, and in ve
in Assynt; in Cornwall; and near Granard in Ireland.

9. Aphrite (i. 349).

10. Lucullite; of which there are three kinds—com

a. Compact lucullite is subdivided into common or bla

α. The common compact. Colour greyish-black; massi
grained, uneven; opaque; semi-hard; streak dark ash-gr
When two pieces are rubbed together, a fetid urinous o
creased by breathing on them. It burns white, but for
sulphuric acid. Its constituents are, lime 53·38, carboni
nesia and oxide of manganese 0·12, oxide of iron 0
chloride and sulphate of potassium with water 2·62 (Joh
in primitive and older secondary rocks. Hills of this u
Assynt in Sutherland. Varieties of it are met with in
the counties of Cork and Galway. It is the *Nero antico*

β. Stinkstone or *Swinestone.* Colour white of many
black, and brown; massive, disseminated, and in distinc
fracture splintery; opaque; semi-hard; streak greyish-
friction; brittle; specific gravity 2·7. The same chemic
Its constituents are, 88 carbonate of calcium, 4·13 silic
iron, 0·58 oxide of manganese, 0·30 carbon, 0·58 lime; s
(John). It occurs in beds, in secondary limestone,
secondary gypsum and beds of clay. It is found in t
resting on red sandstone, and in the parish of Kirbean i
for burning into lime.

b. Prismatic lucullite. Colours black, grey, and brow
distinct concretions; external surface sometimes streal
cleavage threefold; translucent on the edges; semi-hard
rubbed it emits a strongly fetid urinous smell; specific g
is boiled in water, it gives out a transient hepatic odour.
alkaline. It dissolves with effervescence in hydrochlori
siduum. Its constituents resemble those of the prece
brown dolomite, at Building-hill near Sunderland. It
porite.

c. Foliated or *sparry lucullite.* Colours white, grey, and
and crystallised in acute six-sided pyramids; internal
rhomboidal; translucent; semi-hard; brittle; emits
specific gravity 2·65. In other respects similar to the p
at Andreasberg in the Harts.

11. Marl; of which there are two kinds, earthy and
grey colour; consists of fine dusty particles, feebly cohe
light; effervesces with acids; and emits a urinous s
constituents are, carbonate of calcium, with a little alumin

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stone and gypsum formations in Thuringia and Mansfeld. our; is massive, vesicular, or in flattened balls; contains arthy, but in the large masses slaty; yields to the nail; ; brittle; feels meagre; specific gravity 2·4. It intu- nd melts into a greenish-black slag. It effervesces with rbonate of calcium 50, silica 12, alumina 32, iron and an). It occurs in beds in the secondary floetz limestone. nations of Scotland and England.

late. Colour greyish-black; massive, and frequently with nts; lustre glistening; fracture slaty; opaque; shining ble; specific gravity 2·66. It is said to be carbonate of nd bitumen. It occurs in floetz limestone. It frequently etrified fishes, and fossil remains of cryptogamous plants. ameson.)

$C^{11}H^8O^8$ (H. Vohl, N. Ber. Arch. lxxiv. 16).—An acid ic and acetic acids, by treating oil of lime, or oil of rose- potassium and sulphuric acid. As soon as the action is with water, and the limettic acid, which separates as a by repeated solution in aqueous carbonate of potassium, and recrystallisation from alcohol.

talline; volatilises when heated, and forms a crystalline as neither taste nor smell; dissolves sparingly in *water*,

^{6}, obtained by adding nitrate of silver to the acid neu- a powder sparingly soluble in water and blackening on

principle contained in the pips of oranges and lemons. , sparingly soluble in water, ether, and ammonia; easily tash; from the potash-solution it is precipitated by acids. rming a red liquid, from which the limonin is precipitated ves it without alteration. It melts at 124°, and solidifies oling. According to Schmidt's analysis (calculated with arbon), it contains 66·04—65·62 per cent. carbon, and e Schmidt deduced the formula $C^{52}H^{30}O^{13}$. (Bernays, —Schmidt, Ann. Ch. Pharm. li. 338.)

matite. Hydrous Sesquioxide of Iron (See IRON, OXIDES

H^2O^2. *Cupreous Sulphate of Lead. Cupreous Anglesite.* —Occurs in crystals belonging to the monoclinic system. ardness 2·5—3. Lustre vitreous or adamantine. Colour blue. Translucent. Fracture conchoïdal. Analysis by d, 18·0 oxide of copper, 4·7 water = 98·1; by Thomson, ide of copper, and 5·5 water. It occurs at Leadhills, also and, in crystals sometimes an inch long; at Linares in urs altered to cerusite, a change like that of anglesite to il. [2] iv. 117.—Thomson, Phil. Mag. 1840; see p. 402.—

TILBITE.

mineral consisting of arsenite of copper with basic sul- id containing, according to Lindacker's analysis (Jahrb. 28·58 As^2O^3, 6·44 SO^3, 16·15 NiO, 2·90 FeO, and 9·32 nearly with the formula $2Cu(AsO^2)^2.NiSO^4.2NiO.8H^2O$. ardness 2—2·5. Lustre vitreous. Colour verdigris to een to white. It dissolves after longer heating in hydro-)

substance from *Linum catharticum* (Pagenstecher, Ann. w. d. Chem. iv. 924). According to C. Schröder (N. st mode of preparing it is to digest a considerable quantity of lime; mix the filtered yellow liquid with hydrochloric te remaining suspended in the liquid; agitate with ether, allise from the ethereal solution. It forms small white e, heavier than water, dissolving very sparingly in water, ner, somewhat less easily in acetic acid and in chloroform. slightly, the alcoholic solution intensely and persistently

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bitter. Linin melts and decomposes when heated. It gives by
cent. carbon and 4·72 hydrogen; does not evolve ammonia when
lime.

LINNÆITE. Native sulphide of cobalt.

LINOLEIC ACID. *Papaveroleic acid. Trockenölsäure.*—C[36]
and Boudet, Ann. Ch. Phys. [2] lix. 43.—Laurent, *ibid.* lxv. 150
Ann. Ch. Pharm. xxxiii. 113.—Sacc, *ibid.* li. 214.—Schüler, *ibid.* ci.
manns, Jun. Scheik. Onderzoek. i. Stuk. 184.—Gm. xvi. 306).—An
in linseed and poppy oils, and perhaps also in other drying oils. To
oil (or poppy oil) is saponified, and the soap purified by repeated
which it is dissolved in a large quantity of water, and thrown dow
chloride of calcium. The precipitated calcium-salt is washed, pre
in ether, which dissolves out the linoleate of calcium, and leaves th
fatty acids undissolved. The ethereal solution is decomposed by
acid, whereby the linoleic acid is separated, and remains dissolved
solution is drawn off, and the ether distilled at as low a temperatu
stream of hydrogen. There then remains dark-yellow linoleic acid,
in alcohol, and precipitated by ammonia and chloride of barium.
after being washed and pressed, is dissolved in ether, and the w
gradually formed in the solution, are repeatedly recrystallised from
barium-salt the acid is separated by agitating with ether and
pipetting off the ethereal layer of liquid, and distilling off the eth
vacuum over oil of vitriol and a mixture of lime and sulphate of ir
similar method is employed by Oudemanns, who, however, prefer
linoleate of sodium by chloride of calcium in a strongly ammonia
digests linseed oil with oxide of lead and water, at a gentle heat; exh
greasy soap with ether, which leaves margarate (palmitate according
a little basic linoleate of lead undissolved; evaporates the ether
decomposes the residue with hydrochloric acid. The acid thus obtai
boiling water, dissolved in ether, and recovered by evaporating th
decomposes the lead-salt with sulphydric acid, and extracts the
ether.

Properties.—Linoleic acid is a faint-yellow, limpid oil, of specific
14°, having a high refractive power, and a weak acid reaction. It
18°; tastes mild at first, afterwards harsh (Schüler). It is more
oil (Oudemanns). It is insoluble in *water*, but dissolves readily i
in *alcohol*.

Decompositions.—1. On standing in the *air* for ten weeks, the a
cent. oxygen, and becomes viscid and tough (Schüler). It takes u
fresher it is, and thickens, so that at last it will scarcely flow, but
and does not evolve carbonic acid (Oudemanns). A thin layer o
the air forms a varnish; on glass it only becomes tough (Schül
potassium or sodium, containing an excess of alkali, exposed in the f
to the air, absorbs oxygen greedily, and becomes yellow and dry; i
water with dark brown-red colour, and deposits, on addition of hy
brown greasy resin, similar to that produced by the action of nit
2. By *dry distillation*, products are formed, different from those yi
(Laurent).—3. With *nitric acid*, the acid swells up considerably, a
resin, suberic acid, and a little oxalic acid, the last probably deriv
ether (Sacc). *Nitrous acid* and *mercurous nitrate* do not form elaidi
acid. (Pelouze and Boudet; Laurent; Schüler; Oudema

Linoleates.—The mono-acid salts are difficult to obtain pure, an
too small a proportion of base, on account of their easy convers
(Schüler, Oudemanns). They are white, for the most part un
separate from their hot solutions in flakes; by spontaneous eva
obtained in the form of a jelly. When exposed to the air, they bec
odorous. They are soluble in alcohol and ether. (Oudemanns.)

Barium-salt.—The salt produced by mixing chloride of barium wit
a large excess of ammonia has been added, contains a portion of ba
12·04 to 24 per cent. ($C^{32}H^{34}Ba''O^4 = 23·46$ per cent. BaO). It is whi
alcohol on cooling in microscopic crystals, and from ether on sponta
in more distinct crystals. When exposed to the air, or when
boiling with alcohol, it becomes yellow and sticky. It dissolves ve
less easily in alcohol; and is insoluble in water. (Oudemanns.)

The *calcium-salt* resembles the barium-salt. It was only once ob

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ning 9·72 per cent. CaO), and mostly contained a smaller
manna.)
h-green, insoluble in water, and nearly so in alcohol.

olves a large quantity of oxide of lead, and forms there-
ss; with a smaller quantity of oxide of lead it forms a
ure to the air, remains for a long time greasy, and of the
iebig). The ethereal solution of the lead-salt becomes
, and throws down a white basic salt, upon which an acid,
deposited; this last smells like linseed-oil, and shows a
ysis. Exposed to the air in thin layers upon wood, lino-
varnish, but strips off in scales. (Sacc.)
oluble in water.
ver throws down, from the sodium-salt, a white precipitate,
reduction of silver. It dissolves readily in aqueous ammo-
e solution, a portion crystallises out; another portion is
liquid black. (Oudemanns.)
acid is dissolved in caustic soda, salted out with chloride
e residue is freed from chloride of sodium by dissolving it
solution, an acid salt is obtained containing 7·5 per cent.
formula $2C^{16}H^{27}NaO^3.C^{16}H^{28}O^3$; by calculation, 7·75 per

in water.
of the flax plant (*Linum usitatissimum*). The following
Way (Journ. Roy. Agr. Soc. x. pt. 2.):

Composition of Linseed.

	Nitrogen, per cent.	Fat, per cent.	Ash, per cent.	Water, per cent.
. . .	3·60	34·70	5·25	9·45
. . .	3·33	36·00	3·56	8·74
. . .	3·31	38·42	5·64	10·22
. . .	4·60	36·66	2·68	12·33
. . .	5·28	32·77	3·30	11·00
. . .	4·25	33·50	4·08	10·58
. . .	4·29	38·11	4·03	8·57

btained by expressing the fixed oil from linseed grown in
an amount of nitrogen varying from 3·92 to 5·25 per cent.,
ent., ash from 5·45 to 22·66 per cent, water from 6·56 to
ity of albuminous substances calculated from that of the
nples from 25 to above 36 per cent.
gr. Soc. J. new series, No. 69, p. 376) found in linseed,
34·00 oil; 30·73 gum, sugar, and cellulose; 3·33; ash and

xx. 96) has analysed the several parts of linseed with the

nd soluble salts	14
sin and fixed oil	1
. . . . .	2
insoluble in water and in ether	4
sin and fixed oil	6
. . . . .	2
soluble in water	3
insoluble in water and in ether	12
oil	30
. . . . .	5
soluble in water	3
insoluble in water and in ether	18
	100

f linseed, see FLAX (ii. 657).
large quantity of mucilage, which is deposited in the
epidermis, and swells up when the seed is macerated with
e cell-walls. 1 pt. of linseed boiled with 16 pts. water yields
o be drawn out into threads, and forming a dark-coloured

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mass when dry. This crude mucilage contains, in addition to the true
lage, also legumin, albumin, an organic acid, perhaps malic acid, and
chiefly lime, potash, and iron, partly as phosphates, partly united
carbonic acid. Linseed mucilage, precipitated by alcohol, gave 11 p
taining 4 per cent. carbonic acid (Schmidt, Ann. Ch. Pharm. li. 29).

LINSEED OIL. The fixed oil expressed from the seeds *of Lin*
may be taken as the type of the class of oils called drying oils, fro
of drying up, when exposed to the air, to a transparent resinous,
They probably all resemble linseed oil in containing a glyceride of linol
with palmitin (and perhaps stearin), by the varying proportions of which
are determined. In the impure state, they contain also mucus, gu
together with a yellow colouring principle possessed of taste and smel

The cold-pressed oil of fresh linseed is pale yellow, and without di
The commercial oil is dark yellow, and has a sharp penetrating
Specific gravity at 13° = 0·9347 (Schüler, Schübler), 0·9337 (
Jahresber. 1859, p. 701); other statements vary between 0·928 and
gravity at 12° = 0·9395; at 25° = 0·931; at 50° = 0·9125; at 94° =
water at 15° being taken as unity (Saussure). It does not solidify at
(Gusserow), nor at − 28° (Brandis); according to Schüler, it
solid fat at − 18°. It contains, on an average, 78·11 per cent. C, 10·9
(Sacc); the cold-drawn oil contains, on an average, 75·17 per cent.
13·85 O, corresponding to the formula $C^{18}H^{32}O^2$ (Lefort). (See Sau
Ann. Ch. Phys. [2] xiii. 338.)

It contains margarin (palmitin, according to Schüler; stearin
Unverdorben), and a glyceride of linoleic acid (Sacc). By saponifi
$\frac{1}{10}$th margarate, and $\frac{9}{10}$ths linoleate of lead (Gusserow, Kastn. Arch.

Linseed oil exposed to sunshine for some weeks, in contact with an
of an equal weight of protosulphate of iron, becomes limpid and colou
to the air in thin layers, it dries up to a transparent, resinous, moderat
resembling caoutchouc; when heated, however, it does not melt, bu
burns (Leucho, Kastn. Arch. iii. 107). A peculiar fat is produced a
together with a crumbly substance, insoluble in ether (Hoppe, J.
117). Mixed with chalk so as to form a powder, and exposed to
weeks, it dries up completely, and on dissolving out the carbonate
hydrochloric acid and exhausting the residue with ether, a whi
consistence of tar is obtained, which behaves like oleic acid altered by
air. There remains behind resinous linseed oil in the form of a yell
rate mass, which is insoluble in alcohol, ether, volatile and fixed oils,
alcoholic hydrochloric acid into a tarry substance, and dissolves in
(Unverdorben, Schw. J. xvii. 245).

Impure oil, containing mucus or albumin, becomes rancid in the a
in sunshine, and has then a repulsive odour and taste, a dark
reaction. Concerning the formation of ozonised oxygen in the oxidati
see Schönbein (J. pr. Chem. lxxiv. 338). When the oil is boiled
till it loses about $\frac{1}{8}$ of its weight, it becomes thicker, tenacious,
dries up still more readily than in the fresh state to a tough, turpe
scarcely soluble in oils: *Printers' varnish.* (See Ink, p. 272.)

Linseed oil (also nut or poppy oil), heated to about 323°—
and burns quietly, without further heating from without, till tar or c
If the burning be interrupted by closing the vessel, there remains a br
like body which may be used as *birdlime.* When this substance
tinuously with water containing nitric acid (water being added to
violent action of the acid), an odour of acrolein is constantly e
substance becomes solid, of the consistence of plaster, resembles India
longer sticks to the fingers. It is then not completely fusible,
emulsion in sulphide of carbon, shrinks when boiled with conc
potash, dissolves only on addition of water, and is again precipitated f
by acids. This substance is soluble in alcoholic potash and precipit
swells in ether free from alcohol, and partly dissolves in a larger qu
alcohol precipitates it from the solution. In rock-oil it swells wit
also in a little oil of turpentine, but dissolves completely in a larg
remains unaltered on evaporation. Linseed and nut oils yield eight
much of this caoutchouc-like substance as poppy oil (Jonas, N. Br.
J. pr. Chem. xxxvii. 381).

Linseed oil submitted to *dry distillation* gives off, without boiling
which condense to a colourless oil, having an odour of bread; on the

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boil, expands, and yields a distillate of brown em-
mass resembling jelly and caoutchouc remains behind.

linseed oil with red colour, partially crystallising on
e oil takes up, with evolution of sulphydric acid, $\frac{1}{4}$th its
therewith a brown viscid mass: *fatty balsam of sulphur.*
x, N. Br. Arch. ii. 15; also Reinsch. J. pr. Chem. xlii.
cenium (Berzelius); it dissolves nearly $\frac{1}{16}$th *arsenious*
heavier, precipitable by oil of vitriol and hydrochloric
is (W. Henry, Schw. J. ii. 636). *Phosphorus* boiled
arlet colour (Reinsch. J. pr. Chem. xiv. 257). Heated
horus to 75°, the oil becomes brown-black, and after
ance insoluble in linseed oil; $\frac{1}{8}$th phosphorus forms a
e drying oils. (Jonas, N. Br. Arch. lxx. 139.)
with $\frac{1}{3}$rd *iodine*, there pass over, first iodine, then an
rown by iodine; afterwards white vapours of hydriodic
a thick yellowish oil, and at last charcoal, containing
J. pr. Chem. xiv. 263.)
obtained by drenching the oil with 8 or 10 parts of
0° and 80°, and adding bromine by drops as long as the
e excess of bromine, if necessary, by further addition of
rashed with warm water and dissolved in ether; the
h warm water, and the brominated oil thus freed
wn, smells like linseed oil when heated, has a specific
contains 40·77 per cent. bromine, corresponding to the
ted linseed oil, prepared in like manner, is a dark-yellow,
ty 1·088 at 6·5°, and contains 22·62 per cent. chlorine
Pharm. [3] xxiii. 343.)
5 pts. *chloride of sulphur* with 100 pts. linseed oil,
obtained, which are the harder the more chloride of
not attacked by moderately dilute acids and aqueous
onified by concentrated alkalis. They become brown at
t a higher temperature. The addition of 5 per cent.
inseed oil, but does not cause it to harden; the product
e fatty oils. When to a solution of 1 pt. linseed oil in
n, a quantity of chloride of sulphur is added equal to
he mixture remains fluid for some days, and dries up
rra, Compt. rend. xlvii. 878; see also Compt. rend.

py *phosphoric acid*, linseed oil becomes brownish-yellow

colours it yellowish-brown (Gaultier de Claubry),
eh, van Kerckhoff); it coagulates the oil, colours it
and evolves sulphurous and formic acids; and there
ropy, saponifiable mass (Sacc). From this last, water
s which precipitate gelatin: *Hatchett's artificial tannin.*
d oil with 1 volume sulphuric acid of specific gravity
usly, becomes green in 15 minutes (Calvert). When
ith 7½ grs. sulphuric acid containing 90 per cent. H^2SO^4,
(Fehling, Dingl. pol. J. cxxix. 53.)
fuming *nitric acid*. Linseed, hemp, and poppy oils take
with dilute nitric acid an addition of sulphuric acid is
brously shaken mixture of linseed oil with $\frac{1}{4}$th its volume
y 1·18 to 1·22, becomes yellow in 5 minutes; with acid
to brown; with nitro-sulphuric (equal parts of oil of
Calvert, Phil. Mag. [4] vii. 101; J. pr. Chem. lxi. 354).
rm. xiii. 203. Linseed oil shaken with water and very
d after some time, and converted into a varnish (Alm.
4 drams of strong nitric acid into a hundredweight of
nt is formed, with frothing, and the oil is changed to a
(Jonas, Ann. Ch. Pharm. xxxiv. 238).—A mixture of
mercial nitric acid, heated with 4 times its bulk of water,
p, evolves nitric oxide, and forms a tough, elastic resin.
d, and the mother-liquor oxalic and suberic acids. The
again becomes oily, and is then decomposed (the mar-
th formation of suberic and pimelic acids and a volatile

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fatty substance having the odour of butyric acid (Sacc).—With *sili* oil does not form elaidic acid. (Pelouze and Boudet.)

In contact with aqueous *ammonia* and alcohol, it is attacked wi yields a small quantity of warty crystals of an amide which melts at 97°, and dissolves easily in alcohol; it contains, on an average, 75·25 H, and 5·03 N, and has therefore the composition of margaramide, identical. (Rowney, J. pr. Chem. lxvii. 159.)

Linseed oil yields, with *alkalis*, a very soft soap. On heating wit of caustic soda of specific gravity 1·34, it turns yellow and remains By distillation with an excess of alkali, it evolves hydrogen, together v and yields a green distillate. (Al. Müller, *Handwörterb.*, vi. 874.)

Potassium and *sodium* oxidise in linseed oil somewhat more quickl oils, with formation of soap. (Gay-Lussac and Thénard.)

Linseed oil is oxidised with peculiar facility by *acid chromate* dilute sulphuric acid, and yields an acid, strongly-smelling distillate Ann. Ch. Pharm. lxxiii. 199.)

It dissolves oxide of lead when heated, and is decolorised thereby a easily drying, forming what is called *boiled oil* (see Liebig, Ann. C 110; W. Henry, Scher. J. ii. 636; Schindler, N. Br. Arch. xli. 146 *Handwörterb.* iii. 123). When shaken with *basic acetate of lead* a throws down a turbid mucus containing oxide of lead, above which nish containing 4 or 5 per cent. oxide of lead. Exposed to the su *mercuric oxide*, it reduces the mercury to a liquid mass (Fuchs, xx. 200); partial reduction takes place in strong sunshine, the oxide b grey; but it is only when heat is applied, that a small quantity of (Ann. Ch. Pharm. xx. 200.)

Linseed oil dissolves, according to Bucholz, in about 5 pts. of bo of cold alcohol; according to Brandes (Gilb. Ann. xliv. 289), in specific gravity 0·82 and in 1·6 pt. ether.

LIPARITE. Syn. with FLUOR SPAR (ii. 677).

LIPIC ACID. $C^5H^8O^5 = C^5H^6O^4 . H^2O$ according to Lau Phys. lxvi. 169); $C^5H^8O^4$ according to Wirz (Ann. Ch. Pharm. cv formula places it among the homologues of oxalic acid, included in th $C^nH^{2n-2}O^4$. This acid, discovered by Laurent, is produced, together beric, adipic, and other acids, by the action of nitric acid upon oleic, s acid, and is contained in the mother-liquor which remains after the p acids have been separated.

The best mode of preparing it, is to heat oleic acid in a retort fo with an equal weight of nitric acid of ordinary strength, then add fre repeat the operation four or five times. The united solutions are the to a fourth of their bulk, and the concentrated liquid left at rest, t beric acids crystallise out. The remainder of the nitric acid must the the mother-liquor by evaporation as completely as possible, taking c does not blacken from too great concentration; the crystals which consisting of adipic and lipic acids, are dried and dissolved in hot et a few brown impurities undissolved; the solution is left to evaporat and the liquid which covers the crystals is evaporated. The two prod by evaporating the ether are separately dissolved in boiling alcohol, are left to evaporate in the air. By repeating these operations severa are obtained, viz. adipic acid crystallised in rounded tuberculous a and lipic acid in slightly elongated laminæ (Laurent), in translucen of nodular groups of small prisms. (Wirz.)

Lipic acid is moderately soluble in cold *water*. When a few grain on a watch-glass, till partial fusion takes place, the acid crystallise fibrous mass, while a portion volatilises and condenses on the no beautiful needles having the form of prisms with rectangular base.

The acid crystallised from water, contains 1 at. water, which it los the anhydrous acid then condensing in long shining needles (Wirz very suffocating and excites coughing. When deprived of its water it does not melt below 140° or 145° (Laurent); according to Wirz It is very soluble in *alcohol* and *ether*.

Lipic acid is dibasic, the formula of its s lts being $C^5H^6M^2O^4$, whi that of the itaconates (Laurent); $C^5H^6M^2O^4$ (Wirz). The salts sulphuric acid give off lipic acid.

The *ammonium-salt* crystallises in long prisms (Laurent).— separates after a while from a mixed solution of chloride of barium

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, passing into the octahedron (Laurent).—The *calcium-*
manner in square-based prisms, containing, according to
e *cupric salt*, $C^3H^6Cu''O^4$, is obtained, by boiling cupric
reen crystalline scales, which may be freed from adhering
—200° (Wirz).—The *silver-salt* contains $C^3H^4Ag^2O^4$
irz).—The *sodium-salt* crystallises in flat rhombic prisms
(Wirz.)
cid must, however, be regarded as somewhat doubtful.
as impure succinic acid, and Arppe (Ann. Ch. Pharm.
investigation of the products of the action of nitric acid
the same conclusion. He prepared the acids by Laurent's
m oleic acid obtained by saponification of the so-called
tion obtained by evaporating the nitric acid with addition
owder, which, after repeated crystallisation, melted at 127°,
suberic acid mixed with another acid which could be ex-
oved to be azelaic acid (p. 572); the same acid was also
of the suberic acid.

l radicle, C^3H^4, supposed by Berzelius to exist in the
At present however these compounds are regarded as
radical *glyceryl*, C^3H^5. (See Ethers, ii. 519, and Glyce-

applied to bodies in that peculiar state of aggregation, in-
l and the gaseous, in which the particles are free to move
irections, but do not exhibit the constant tendency to fly
istic of the gaseous state.* The conditions which are
s particular state of aggregation have been already con-
ie dynamical theory of heat (p. 133).

balsam produced from a large tree (*Liquidambar styraci-*
Florida, and Mexico.
l of liquidambar, which is obtained by making incisions
diately in vessels to protect it from the air, and decanted
portion of the opaque balsam which settles to the bottom.
nick oil, is transparent, of amber-yellow colour, and has an
ax, but more agreeable; its taste is aromatic and irritates
considerable quantity of benzoic or cinnamic acid, and a
ongly. Treated with boiling alcohol, it leaves only a small
id becomes turbid on cooling.
ar proceeds either from the opaque deposit above men-
balsam which have run down the stem of the tree, and
e air. It has the consistence of very thick turpentine or
whitish; its odour is less strong and more agreeable than
d; taste, sweet and aromatic, but irritating. It contains
r cinnamic acid. By long exposure to the air it solidifies
ost transparent. It was formerly sold under the name of
., iv. 386.)

ON OF. When two liquids of different density, and
in contact, diffusion takes place between them, much in the
ses, excepting that, as the particles of the liquid are less
he gas, the rate of diffusion is slower. The phenomena of
nutely investigated by Graham, in two classical series of
Philosophical Transactions for 1850 and 1862, also in the
iety, iii. 60, 257; iv. 83, and xv. 216; and important con-
ave also been made by Fick, Simmler and Wilde,

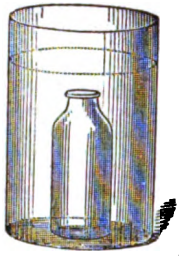
s with the nature of the liquids, the temperature, and in
ie degree of concentration.
Solutions. The apparatus used in Graham's first series
a set of phials of nearly equal capacity, cast in the same
by grinding to a uniform size of aperture. The phials
a neck 0·5 inch in depth, and aperture 1·25 inch wide;
l to 2080 grains of water or between 4 and 5 ounces. For
glass water-jar was also provided 4 inches in diameter and

fluid" as synonymous with liquid; but this is incorrect; *fluid* is, pro-
solid, and includes both liquid and gas.

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The diffusion-phial was filled with the saline solution, sal-ammoniac the base of the neck, or more correctly to a distance of 0·5 inch f surface of the lip. The neck of the phial was the

Fig. 708.



distilled water, a light float being first placed on the solution, and care being taken to avoid ag the phial had been placed within the jar, water the jar, so as to cover the open phial to the de which required about 20 ounces of water. The the phial is thus allowed to communicate freely in the jar. The diffusion is interrupted by placi of ground glass on the mouth of the phial, and ra out of the jar. The amount of salt diffused, cal sion-product, or diffusate, is ascertained by water in the jar to dryness, or, in the case of ch cipitating with nitrate of silver.

The results of several series of experiments made are given in the following table, the second column the quantity of salt in 100 pts. of the solution, one per cent. of sal 20·8 grains; the third, the time of diffusion; the fourth, the temp Fahrenheit scale; the fifth, the quantity of salt diffused in grains:—

TABLE I.—DIFFUSION OF SALINE SOLUTIONS.

Substance.	Per cent.	Days.	Fahr.
Hydrochloric acid	1	5	51
	2	5	51·0
	2	5	59·7
	4	5	51·0
	8	5	51·0
Hydriodic acid	2	5	51·0
Hydrobromic acid	2	. .	59·7
Bromine	0·864	10	60·1
Hydrocyanic acid	1·766	5	64·2
Hydrated nitric acid (NO^6H)	1	5	51·2
	2	5	51 2
	4	5	51·2
	8	5	51·2
Hydrated sulphuric acid (SO^4H)	1	10	49·7
	2	10	49·7
	4	10	49·7
	8	10	49·7
Chromic acid	1·762	10	67·3
Acetic acid ($C^4H^4O^4$)	2	10	48·8
	4	10	48·8
	8	10	48·8
Sulphurous acid	1	10	68·1
	2	10	68·1
	4	10	68·1
	8	10	68·1
Ammonia	1	4·04	63·4
	2	4·04	63·4
	4	4·04	63·4
	8	4·04	63·4
Alcohol	2	10	48·7
	4	10	48·7
	8	10	48·7
Nitrate of barium	1	11·43	64·1
	2	11·43	64·1
	4	11·43	64·1
	8	11·43	64·1
Nitrate of strontium	0·82	11·43	51·5
Nitrate of calcium	1	11·43	64·1
	2	11·43	64·1
	4	11·43	64·1
	8	11·43	64·1
Acetate of barium	1	16·17	53·5

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TABLE I.—*continued.*

	Per cent.	Days.	Fahr.	Diffu-ate.
.	1	16·17	53·1°	7·84
	1	8·57	63·0	6·32
	2	8·57	63·0	12·07
.	4	8·57	63·0	23·96
	8	8·57	63·0	45·92
	1	8·57	63·0	6·09
	2	8·57	63·0	11·66
.	4	8·57	63·0	23·56
	8	8·57	63·0	44·46
	1	11·43	63·8	7·92
	2	11·43	63·8	15 35
.	4	11·43	63·8	30·78
	8	11·43	63·8	61·56
	1	11·43	50·8	6·51
.	1	11·43	50·8	6·63
.	1	11·43	50·8	6·49
.	1	11·43	50 8	6·44
.	1	11·43	50·8	6·29
.	1	11·43	50·8	6·17
.	1	11·43	50·8	6·06
.	1	11·43	53·5	6·30
	1	16·17	65·4	7·31
	2	16·17	65·4	12·79
	4	16·17	65·4	23·46
.	8	16 17	65·4	42·82
	8	16·17	62·8	42·66
	16	16·17	62·8	75·06
	24	16·17	62·8	102·04
	1	16·17	65·4	6·67
	2	16·17	65·4	12·22
	4	16·17	65·4	23·12
.	8	16·17	65·4	42·26
	8	16·17	62·8	39·62
	16	16·17	62·8	74·40
	24	16·17	62·8	101·42
	1	16·17	65·4	5·48
	2	16·17	65·4	10·21
.	4	16·17	65·4	19·28
	8	16·17	65·4	33·52
	2	7	63·4	13·61
.	4	7	63·4	26·34
	8	7	63·4	51·88
	2	7	63·4	12·35
.	4	7	63·4	23·56
	8	7	63·4	47·74
	1	7	63·4	6·32
	2	7	63·4	12·37
.	4	7	63·4	24·96
	8	7	63·4	48·44
	2	7	63·4	12·14
.	2	7	59·8	12·18
.	2	7	59·8	12·14
.	2	5·716	59·8	12·24
.	2	5·716	59·8	12·46
.	2	5·716	59·8	12·51
.	1	5·716	59·8	5·99
	1	8·08	68·2	7·23
	2	8 08	68·2	14·05
.	4	8·08	68·2	26·72
	8	8·08	68·2	52·01
	1	8·08	68·2	6·91
.	2	8·08	68·2	13·65

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TABLE I.—*continued.*

Substance.	Per cent.	Days.	Fahr.	Diffusate.
Bicarbonate of ammonium	4	9·87	68·2°	27·00
	8	9·87	68·2	50·10
Bicarbonate of sodium	1	9·87	68·2	7·31
	2	9·87	68·2	13·81
	4	9·87	68·2	26·70
	8	9·87	68·2	52·38
Hydrate of potassium	1	4·04	63·3	6·56
	2	4·04	63·3	12·84
	4	4·04	63·3	25·04
	8	4·04	63·3	52·24
Hydrate of sodium	1	4·95	63·2	5·81
	2	4·95	63·2	11·09
	4	4·95	63·2	20·86
	8	4·95	63·2	40·44
Carbonate of potassium	1	8·08	63·6	6·13
	2	8·08	63·6	11·92
	4	8·08	63·6	22·88
	8	8·08	63·6	45·44
Carbonate of sodium	1	9·9	63·4	6·02
	2	9·9	63·4	11·70
	4	9·9	63·4	21·42
	8	9·9	63·4	39·74
Sulphate of potassium	1	8·08	60·2	6·16
	2	8·08	60·2	11·60
	4	8·08	60·2	22·70
	8	8·08	60·2	43·92
Sulphate of sodium	1	9·9	59·9	6·33
	2	9·9	59·9	12·00
	4	9·9	59·9	21·96
	8	9·9	59·9	41·38
Sulphite of potassium	2	8·08	59·5	11·63
Sulphite of sodium	2	9·9	59·5	11·83
Hyposulphite of potassium	2	8·08	59·7	12·37
Hyposulphite of sodium	2	9·9	59·9	11·89
Sulphovinate of potassium	2	8·08	59·7	12·60
Sulphovinate of sodium	2	9·9	59·5	13·03
Oxalate of potassium	1	8·08	59·9	6·20
	2	8·08	59·9	12·17
	4	8·08	59·9	2·4
	8	8·08	59·9	42·82
Oxalate of sodium	1	9·9	59·9	6·24
Acetate of potassium	1	8·08	60·2	6·44
	2	8·08	60·2	12·52
	4	8·08	60·2	23·44
	8	8·08	60·2	47·26
Acetate of sodium	1	9·9	59·5	6·67
	2	9·9	59·5	12·46
	4	9·9	59·5	25·04
	8	9·9	59·5	48·04
Tartrate of potassium	2	8·08	59·9	10·96
Tartrate of sodium	2	9·9	59·5	10·65
Hydrochlorate of morphine	2	11·43	64·1	11·60
Hydrochlorate of strychnine	2	11·43	64·1	11·49

These experiments, and a number of others made in a similar manner, lead to the following general conclusions:

1. Different salts, in solutions of equal strength, diffuse unequally in equal times.

2. With each salt, the rate of diffusion increases with the temperature, and at any given temperature, is proportionate to the strength of the solution, at least when the quantity of salt dissolved does not exceed 4 or 5 per cent.

Later experiments (Chem. Soc. J. xv. 235) have shown that diffusion increases at a higher, though not greatly higher, rate than the temperature, and that the more

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, the less does it gain in diffusiveness by rate of
e acid the rate of diffusion was found to increase as

t 15·55 C. (60° F.) = 1
26·66 C. (80° F.) = 1·3545
37·77 C. (100° F.) = 1·7732
41·88 C. (120° F.) = 2·1812

uidiffusive substances which coincide in many cases
but are, on the whole, more comprehensive than the
f diffusion is exhibited by hydrochloric, hydrobromic,
orides, iodides, and bromides of the alkali-metals; by
um, and calcium; the sulphates of magnesium and

s, it is found that the squares of the times of equal
ne same strength, stand to one another in a simple
e diffusate from a solution of nitrate of potassium in
ined from an equally strong solution of carbonate of
s which are to one another as 1 : $\sqrt{2}$ = 1·414. Similar
er cent. solutions of nitrate and sulphate of potassium,
g obtained in 3·5 and 4·95 days, in 7 and 9·9 days, and
ith hydrate and nitrate of potassium, and with nitrate
e times of equal diffusion of 1 per cent. solutions of
loride of sodium, were to one another as $\sqrt{2}$: $\sqrt{3}$.
xperiments (ii. 812), the squares of the times of equal
another in the ratio of their densities. Hence, by
t the molecules of these several salts, as they exist in
ch are to one another as the squares of the times of
tion-densities of sulphate, nitrate, and hydrate of potas-
squares of the numbers 4, 2 and 1, that is as 16, 4 and 1,
r to relate to a kind of molecules different from the
ts of which are either equal, or bear to one another a

the solution of another salt takes place with nearly the
er; at least, when the solutions are dilute. Graham
f a 4 per cent. solution of carbonate of sodium, is not
ce of 4 per cent. of sulphate of sodium in the liquid
per cent. solution of nitrate of potassium, by the same
onium. The presence of 4 per cent. of sulphate of
of carbonate of sodium by only $\frac{1}{8}$ of the whole. In
ation would probably be greater. There is, indeed,
henomena of liquid diffusion are exhibited in their
solutions, the effect of concentration, like that of
produce a departure from the normal character.
wever, materially affected when the liquid atmosphere
he diffusing salt. The consideration of this case leads to
tion of particles of a dissolved substance in a solution of
eneral law which regulates such movements appears to
hich a soluble salt diffuses from a stronger into a weaker
he difference of concentration between two contiguous
et been experimentally demonstrated in a sufficient
completely; but in the case of chloride of sodium, it
the following experiments of Fick. (Phil. Mag. [4]

n at both ends, was cemented into a vessel completely
cylindrical space filled up with water, and the whole
ning water. The apparatus was then left to itself for
jar being from time to time taken out and renewed.
liquid in the tube, being in contact with undissolved
aturated, while the uppermost layer, which is in contact
salt at all, a certain normal state of diffusion will
oughout the length of the tube, characterised by the
stratum will, in a given time, give up to the stratum
h salt as it receives from the one below. When this
of the successive strata decrease from below upwards
This law of decrease was verified experimentally by
ious depths, a glass bulb suspended from the arm of a
weights in the opposite scale. This law of decrease,

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nowever, is true only with regard to cylindrical columns of liquid, or the horizontal section is of uniform magnitude. In other cases, the l density may be calculated according to the form of the vertical sec shaped tubes Fick has shown that the results of calculation agr experiment.

Now let K denote the quantity of salt which, in the normal s passes, in a unit of time, through a unit of horizontal section of a whose height is equal to the unit of length; this quantity is call *coefficient;* also, let Q be the quantity of salt which, in the time mouth of the tube into the water-atmosphere; h, the height of horizontal section; and d, the density of the liquid at the bottom; t

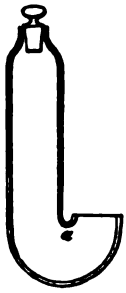
$$Q = K . d . \frac{h}{s} t.$$

Hence, with a tube of given dimensions, and a solution of kno density at the bottom, the *diffusion-coefficient* K, of any salt may be the quantity Q, diffused out in a given time.

This method has been applied by Fick only in the case of chlorid is, in fact, though simple in principle, somewhat inconvenient of appli of the long time—at least fourteen days—which must elapse before th attained.

Another method of determining the diffusion-coefficient of a salt has Jolly, and applied in several cases by Beilstein (Ann. Ch. Pharm.

Fig. 709.



apparatus used consists of a glass tube (*fig.* 709), ab long, bent round at the bottom, and cut off near the level of the orifice is not much more than a milli bottom of the bend. The upper end of the tube is sl and closed with a stopper. This tube is filled with a s concentration, and fixed upright within a jar of wat the tube being two or three lines below the level of salt then immediately begins to diffuse into the water, near the orifice becomes diluted, it passes round the b part of the tube, its place being supplied by more con from above. With this apparatus, Beilstein has obta ing diffusion-coefficients (taking that of chloride of pota for solutions containing 4 per cent. of salt, and at the 6° C. (42·8° F.)

TABLE II.—*Diffusion-coefficients.*

Chloride of potassium	1·0000	Sulphate of potassium	
Nitrate of potassium	0·9487	Carbonate of sodium	
Chloride of sodium	0·8337	Sulphate of sodium	
Bichromate of potassium	0·7543	Sulphate of magnesium	
Carbonate of potassium	0·7371	Sulphate of copper	

Beilstein infers from his experiments, that the rate of diffusion proportional to the difference of density of two contiguous strata, b somewhat greater ratio.

Simmler and Wilde (Pogg. Ann. c. 217) are of opinion that th ment of Beilstein's results with this law arises from a defect in experimenting. Beilstein's calculations, indeed, are based on the sup strength of the solution in the tube (*fig.* 709), though constantl uniform at any instant of time throughout the entire length; wher sideration will show that the density near the orifice must be less t larger arm of the tube, and in this arm less than near the bottom of the liquid must stagnate to a certain extent. From this source of er of observation is free. Simmler and Wilde, however, propose other of execution than Fick's, and not subject to the necessity of waiting state of diffusion is established. One of these methods is similar by Graham (p. 706), excepting that the vessel containing the solut cylindrical, a condition which greatly simplifies the calculations; and, placed at the bottom of the water-jar, is supported on a stand, so as to within a line or two below the surface of the water; the salt, as it dif made to flow over the sides of the vessel and fall to the bottom, leavin of pure water above. Another method proposed by the same authors saline solution in a vessel having the form of a triangular prism, aud

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ent depths below the surface by observation of the indices

periments (Phil. Trans. 1862, part i.; Chem. Soc. J. xv.
ss jar, in which the salt is allowed to rise from below in a
rs were 152 mm. (6 inches) in height, and 87 mm. (3·45
ting, seven-tenths of a litre of water were first placed in
f a litre of the liquid to be diffused was carefully conveyed
means of a fine pipette. The whole fluid column then
) in height. As much as five or six minutes of time were
pette at the bottom of the jar, and extremely little dis-
the superincumbent water, as could be distinctly seen
y the pipette was coloured. The jar was then left undis-
proceed, the experiments being always conducted in an
early constant temperature. When a certain time had
terrupted by drawing off the liquid from the top by means
d deliberately, as the liquid had been first introduced, in
tres, or one-sixteenth of the whole volume. The open end
on was kept in contact with the surface of the liquid in
quid drawn off was received in a graduated measure. By
parately, the quantity of salt which had risen into equal
n was ascertained. A particular advantage of this method
of ascertaining the absolute rate or velocity of diffusion,
e the distance which a salt travels per second in terms of
must enter into all the chronic phenomena of physiology,
ence not unlike the time of the falling of heavy bodies in

-Crystalloids and Colloids.

fusion has been considered in the preceding pages, though
versities in their diffusive mobility, all belong to the more
o them is another class, which are much less diffusive,
ed from the former by several well-defined physical and
ly by the absence of the power to crystallise. Such are
d alumina, and other metallic oxides of the aluminous
soluble form; also starch, dextrin and the gums, caramel,
etable and animal extractive matters. These bodies are
elatinous character of their hydrates. Although often
y are held in solution by a most feeble force. They appear
city of acids and bases, and in all the ordinary chemical
r hand, their peculiar physical aggregation, together with
erred to, appears to be required in substances that can
esses of life. The plastic elements of the animal body are
tin appears to be its type, substances of this class may be
κόλλη, glue), and their peculiar form of aggregation, as
ter. Opposed to the colloïdal is the crystalline condition.
er form may be classed as *crystalloïds*. The distinction is
lecular constitution.

in the ordinary sense, colloïds possess a compensating
g out of their physical properties. While the rigidity of
ts out external impressions, the softness of the gelatinous
nd enables the colloïd to become a medium for liquid dif-
e same penetrability appears to take the form of cemen-
exist at a high temperature. Hence a wide sensibility
external agents. Another and eminently characteristic
utability. Their existence is a continued metastasis. A
his respect to water while existing liquid at a temperature
t, or to a supersaturated saline solution. Fluid colloïds
ous modification; and they often pass under the slightest
o the second condition. The solution of hydrated silicic
obtained in a state of purity, but it cannot be preserved.
or weeks in a sealed tube, but is sure to gelatinise and
Nor does the change of this colloïd appear to stop at that
ms of silicic acid, deposited from water, such as flint, are
during the geological ages of their existence, from the
crystalline condition (H. Rose). The colloïdal is, in fact,
the crystalloïdal being the statical condition. It may be

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looked upon as the probable primary source of the force appearing in
of vitality. To the gradual manner in which colloïdal changes take
always demand time as an element), may the characteristic protracti
organic changes also be referred.

The following experiments made by the method of jar-diffusion (p. 7
difference of diffusibility of colloïds, namely gum, tannin, or caram
with the crystalloïdal substances, chloride of sodium, sulphate of magne
sugar.

TABLE III.—*Diffusion of* 10 *per cent. solutions* (10 *grms. of substanc*
centimetres of liquid) *into pure water, after fourteen days, at* 10° (

Number of stratum (from above downwards).	Chloride of sodium.	Sulphate of magnesium, at 10°.	Sugar.	Gum.	Tannin.	Albu 12°—
1	·104	·007	·005	·003	·003	
2	·129	·011	·008	·003	·003	
3	·162	·018	·012	·003	·004	
4	·198	·027	·016	·004	·003	
5	·267	·049	·030	·003	·005	
6	·340	·085	·059	·004	·007	. .
7	·429	·133	·102	·006	·017	. .
8	·535	·218	·180	·031	·031	·0
9	·654	·331	·305	·097	·069	·0
10	·766	·499	·495	·215	·145	·0
11	·881	·730	·740	·407	·288	·1
12	·991	1·022	1·075	·734	·556	·3
13	1·090	1·383	1·435	1·157	1·050	·8
14	1·187	1·803	1·758	1·731	1·719	1·8
15 and 16	2·266	3·684	3·783	5·601	6·097	6·7
	9·999	10·000	10·003	9·999	9·997	10·0

Here the superimposed column of water being 111 millimetres (4·3
the chloride of sodium is found to have diffused in sensible quantity
could have risen higher. The top of the diffusion-column of sulphate
and likewise that of sugar, appear to have just reached the top of t
fourteen days of the experiment. But the colloïds, gum, tannin, albumi
exhibit a great falling off in the rate of diffusion. Gum and tannin d
be carried by diffusion higher than the seventh stratum, the minute quan
the higher strata, which together do not exceed 0·02 grm., being doub
of accidental dispersion, arising probably from a movement of the upp
sioned by slight inequalities of temperature. The diffusion of albumin
is still slower.

By continuing the diffusion of different substances till equal quantiti
out, the following results were obtained:

Approximate times of Equal Diffusion.

Hydrochloric acid	1
Chloride of sodium	2·33
Sugar	7
Sulphate of magnesium . . .	7
Albumin	49
Caramel	98

The diffusion of hydrochloric acid in three days corresponds with t
chloride of sodium in seven days. Hydrochloric and the allied hydrac
monobasic acids, are the most diffusive substances known.

The diffusion process in alcohol appears to be several times slower
The following table exhibits the results of experiments on three subst
in alcohol, and placed under a column of alcohol, the experiments be
exactly as described at p. 700.

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per cent. solutions of Iodine and Acetate of Potassium in alcohol in seven days.

odine at 14°.	Acetate of potassium at 14°—15°.	Resin at 14·5°.
·028	·055	·017
·033	·057	·017
·046	·061	·018
·038	·063	·017
·037	·064	·019
·039	·066	·020
·081	·070	·022
·143	·071	·024
·263	·072	·025
·417	·095	·080
·637	·285	·210
·936	·619	·498
1·235	1·157	·992
1·506	1·907	1·700
4·561	5·358	6·341
10·000	10·000	10·000

Liquid Diffusion to Chemical Analysis.

less separated by their unequal diffusibility. A solution ium, and 1 pt. carbonate of sodium in 10 pts. of water *g.* 708), yielded in 10 days at 15° a diffusate containing um to 36·4 pts. carbonate of sodium; the diffusate in lts in nearly the same proportion. Inequality of diffu- sed by mixture, so that the actual separation is greater elative diffusibilities of the mixed substances.

ed by the method of jar-diffusion at p. 700; when a d at the bottom of the jar, the more diffusive salt tra- ly, showing itself first, and always most largely, in the able shows the results obtained with a mixture of equal ium and sodium.

mixture of 5 per cent. of Chloride of Potassium, and ride of Sodium, for seven days at 12°—13°.

Chloride of potassium.	Chloride of sodium.	Total Diffusate.
·018	·014	·032
·025	·015	·040
·044	·014	·058
·075	·017	·092
·101	·034	·135
·141	·063	·204
·185	·104	·289
·252	·151	·403
·330	·212	·542
·349	·351	·700
·418	·458	·876
·511	·559	1·070
·552	·684	1·236
·615	·772	1·387
1·385	1·551	2·936
5·001	4·999	10·000

ether 561 milligrammes, of which 404 milligrammes, or three-fourths, are chloride of potassium. We have to

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descend to the tenth stratum before the salts are found in equal p progression is then inverted, and chloride of sodium comes to pre lower strata.

It is evident that the preceding experiment might be so condu away the chloride of potassium, and leave below a mixture containing c in relative excess, to as great an extent as the chloride of potassium i the last experiment.

Further, the mixture in which chloride of potassium was concentra ment described, so as to form 72 per cent. of the whole mixture, subjected to diffusion in the same manner. In an experiment upon grms. of chloride of potassium and 2·5 grms. of chloride of sodiu strata gave 640 milligrms. of salt, of which 610 milligrms., or 95·3 chloride of potassium. It is obvious that, by repeating this diffusi sufficient number of times, a portion of the more diffusive salt migh last in a state of sensible purity.

The preceding example illustrates the separation of unequally di bases; the following example represents, on the other hand, the separa diffusive acids united with a common base. Chloride and sulphate separately in the phial experiments in the proportion of 1 to 0·707.

TABLE VI.—*Diffusion of 5 per cent. of Chloride of Sodium and anhydrous Sulphate of Sodium, for 7 days, at* 10°—10°

Number of stratum.	Chloride of sodium in grammes.	Sulphate of sodium in grammes.	Total diffusate i grammes
1	·009	. .	·009
2	·012	·001	·014
3	·024	·005	·026
4	·038	·003	·041
5	·060	·006	·066
6	·095	·012	·107
7	·141	·029	·170
8	·203	·059	·262
9	·278	·115	·393
10	·360	·205	·565
11	·473	·317	·790
12	·560	·507	1·067
13	·637	·694	1·331
14	·718	·909	1·627
15 and 16	1·390	2·141	3·531
	4·999	5·000	9·999

Here the separation is still more sensible than with the bases. strata contain 263 milligrammes of salt, of which 239 milligrammes cent., are chloride of sodium. The salt of the upper eight strata milligrammes, of which 583 milligrammes, or 83·9 per cent., are chlo

On comparing the diffusion of a mixture of equivalent quantities of c and sulphate of potassium with that of a mixture, also in equivale chloride of potassium and sulphate of sodium, it was found that th metals is not affected by the acid with which each of them is ori This result is quite in harmony with Berthelot's view, that the aci indifferently combined, or that a mixture of chloride of potassium sodium is the same thing as a mixture of chloride of sodium and sulph when both mixtures are in the state of solution. With two acids g their affinity for bases, however, the result might possibly be differen

In some cases, diffusion is also capable of effecting the decompos compounds. Thus, when a solution of common alum is allowed to d the sulphate of potassium passes out more rapidly than the sulphate o solution of sulphate of potassium in lime-water left to diffuse into a diffusate containing hydrate of potassium; similarly with sulphate sulphates of potassium and sodium are also decomposed by carbonat solved in carbonic acid water, when the liquid is allowed to diffuse The chlorides of potassium and sodium are not sensibly decomposed

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solutions of lime-water and sulphate of calcium are
cent. of chloride of sodium dissolved in the mixture, and
o pure water, scarcely a trace of hydrate of sodium is
n of sulphate of calcium, with an addition of 2 per cent.
at the boiling point for half an hour, and the solution
vards with an equal volume of lime-water, and diffused
he diffusate in three cells is found to contain 0·234
·371 sulphate of sodium. It appears, then, that more
um is possible for mixed solutions of sulphate of calcium
solutions of these salts may be mixed without decom-
ormation of sulphate; but, on heating, this change is
phate of sodium being formed, and continuing to exist
he decomposition of that salt alone by hydrate of calcium
used hydrate of soda. As the effects of time and tem-
it is possible that the same decomposition might take
after a considerable time. If such be the case, we have
h the alkaline carbonates required by plants may be
otassium and sodium, as well as from the sulphates; for
lly present, will convert those chlorides into sulphates.
the earth is moistened by rain is peculiarly favourable
e soluble salts of the soil may be supposed to be carried
pth, by the first portion of rain which falls, while they
e of nearly pure water, in the moisture which falls last
m of the soil. Diffusion of the salts upwards into the
l decompositions, must necessarily ensue. The salts of
ch are most required for vegetation, possess the highest
The pre-eminent diffusibility of the alkaline hydrates
in the soil by hydrate of calcium, particularly as quick-
g to grass-lands. (Graham.)

4.—Dialysis.

colloïd class (p. 710) possess a property which is very
arations. The jelly of starch, that of animal mucus, of
lose (ii. 826), and other solid colloïdal hydrates, all of
soluble in cold water, are themselves permeable when in
highly diffusive substances. But such jellies greatly
diffusive substances, and cut off entirely other colloïd
at may be in solution: in this respect they resemble
e of separation by diffusion through a septum is called
colloïdal septum produces this separating effect. Thus,
aper, well sized with starch. and having no porosity, be
depression made in its centre, and a mixed solution of
taining 5 per cent. of each substance poured upon it, the
water while the gum remains above, so that, after twenty-
ound to contain about three-fourths of the whole sugar, in
llise when the liquid is evaporated over the water-bath.
ower to act as a filter; it is mechanically impenetrable,
ixed liquid as a whole. Molecules only permeate this
molecules also are moved by the force of diffusion. But
starch with which the paper is sized, is not directly
diffusion of either the sugar or the gum, being in a state of
mbination. The hydrated compound itself is solid, and
er, with other crystalloïds, can separate water, molecule
ted colloïd, such as starch. The sugar thus obtains the
usion, and makes its way through the gelatinous septum.
enting, as a colloïd, an affinity for water of the feeblest
te that liquid from the gelatinous starch, and so fails to
age outwards by diffusion.

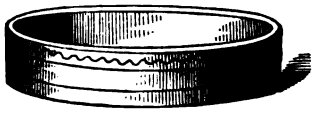
rough a firm jelly appears to proceed at nearly the same
is strikingly shown by the following experiment.
sodium and 2 grammes of the Japanese gelatin, or gelose
her in so much hot water as to form 100 cub. cents. of
empty diffusion-jar and allowed to cool, this liquid set
lower part of the jar, and containing of course 10 per
Instead of placing pure water over this jelly, it was
vater containing 2 per cent. of the same gelose, cooled so

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far as to be on the point of gelatinising, the jar at the same time
cooling mixture in order to expedite that change. The jar with its
left undisturbed for eight days at the temperature 10°. After the
the jelly was removed from the jar in successive portions of 50 cub
the top, and the proportion of chloride of sodium in the various
The results were very similar to those obtained in diffusing the sam
pure water, excepting that the diffusion in the gelose appeared more
days than diffusion in water for seven days. With a coloured crysta
chromate of potassium, the gradual elevation of the salt to the top
plainly seen. On the other hand, the diffusion of a coloured colloid
through the jelly, appears scarcely to have begun after the lapse of
diffusion of a salt into the solid jelly may be regarded as cementa
form.

The most suitable of all substances for a dialytic septum is De la
parchment or parchment-paper (i. 819), which is unsized p
short immersion in sulphuric acid, or in chloride of zinc. Paper
acquires considerable tenacity, and when wetted, expands and be
evidently admitting of hydration. In the wetted state, parchment-p
applied to a light hoop of wood, or better, to a hoop made of s
2 inches in depth and 8 or 10 inches in diameter, so as to form a ve
form (*fig.* 710). The disc of parchment-paper used should excee
hoop to be covered by 4 inches, so as to rise well round the hoop.

Fig. 710.



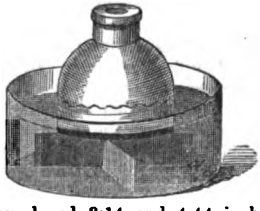
to the hoop by string, or by
but should not be firmly secu
ment-paper must not be poro
will be ascertained by sponging
with pure water, and then obs
spots show themselves on the o
defects may be remedied by ap
min, and then coagulating the s
De la Rue recommends the use of albumin in cementing parchment
thus be formed into cells and bags very useful in dialytic experim
fluid to be dialysed is poured into the hoop upon the surface of th
to a small depth only, such as half an inch. The vessel described
floated in a basin containing a considerable volume of water, in or
egress of the diffusive constituents of the mixture. Half a litre of
twenty-four hours, gave its crystalloïdal constituents to the external
evaporated by a water-bath, yielded a white saline mass. From t
extracted by alcohol in so pure a condition as to appear in crystal
evaporation of the alcohol.

For operating on smaller quantities of liquid, a small glass bell jar
bottom, as shown in *fig.* 711, may be used. *Figs.* 712, 713 show co
supporting the instrument in a basin or a jar of water. In Mr. Gra

Fig. 711.



Fig. 712.





two sizes of bulb were employed, 3·14 and 4·44 inches in
diameter, the dialytic septa having areas very nearly of $\frac{1}{100}$
and $\frac{1}{200}$ of a square metre (15·6 and 7·8 square inches).
With 100 cub. cents. of liquid (the quantity usually em-
ployed) the septum of the smaller instruments was covered
to the depth of 20 mm. (0·8 inch) and the septum of the
larger to a depth of 10 mm. (0·4 inch). The thinner the
stratum, the more exhaustive the diffusion in a given time.
When a considerable diffusion is desired within 24 hours, it is gen
to cover the septum deeper than 10 or 12 mm. (half an inch).

Numerous experiments on the diffusion of crystalloïds through
septa, such as gelatinous starch, coagulated albumin, gum-tragacant

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, all tended to prove how little the diffusive process is in-tion of colloïd matter. Salts appear to preserve their usual ged. The same partial separation of mixed salts is observed With a mixture, for instance, of equal parts of chlorides a dialyser, the first tenth part of the mixture which passed st of 59·17 per cent. of chloride of potassium and 40·83 m. Double salts also, such as alum, and the sulphate of admit of being resolved into pairs of unequally diffusive ed upon the dialyser, as they are in the water-jar. The diffusion appears, however, to be diminished in dialysis, at r septum. Thus the diffusion from a 2 per cent. solution onstant period of three hours, was—

		Ratio.
C. . . .	0·738 grm.	1·00
. . .	0·794 grm.	1·07
. . .	0·892 grm.	1·20
. . .	1·017 grm.	1·37

er alone, without the septum, would have been doubled by instead of being increased one-third only as above.

its the rate of diffusion of several substances, both crys-red with chloride of sodium as a standard. The larger nd the parchment-paper was changed in each experiment, nounted to 2 grms., the depth of liquid in the dialyser to d the surface of the septum to 0·01 square metre (15·6

ough Parchment-paper during twenty-four hours, at 12°.

t. solutions.	Diffusate in grammes.	Proportional diffusate.
um . . .	1·657	1·000
. . .	1·690	1·020
. . .	1·404	·847
. . .	1·166	·703
. . .	·835	·503
. . .	·783	·472
. . .	·517	·311
citron . .	·305	·184
ood . .	·280	·168
. . .	·265	·159
neal . . .	·086	·051
. . .	·050	·030
us . . .	·033	·019
. . .	·009	·005

e were actually diffused from 1 per cent. solutions, and the plied by 2. The crystallisable principles, theine, salicin, tly more diffusible than gallo-tannic acid, or than gum, as h inequality of rate is likely to facilitate the separation of agency of dialysis.

tion of Colloïd Substances by Dialysis.

colloïd substances may be effected with great advantage by ser. Accompanying crystalloïds are eliminated, and the tate of purity. The purification of soluble colloïds can ner known means, and dialysis is evidently the appropriate ies free from crystalloïds.

obtained by pouring silicate of sodium into water acidu-, was placed upon a parchment-paper dialyser, and allowed ter being occasionally changed, a quantity of silicic acid mounting, after the lapse of five days, to seven-eighths of d the solution of silicic acid which subsequently passes drochloric acid and chloride of sodium as not to give a ilver.

a peculiar class of compounds, which like itself, are col-rom the ordinary silicates. These compounds, which may

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be called collisilicates or co-silicates, appear to contain an aci
weight than ordinary silicic acid. Cosilicic acid, like gallotannic, g
colloïdal acids, unites with *gelatin*, forming a cosilicate of gelatin, wh
on mixing the solutions of silicic acid and gelatin; but, like the gal
varies in composition according as the one or the other constituent is
Cosilicic acid also precipitates both *albuminic acid* and pure *casein*.

The true hydrated alumina, also Crum's metalumina (i. 1
soluble by dialysing solutions of these oxides in the chloride and ac
metal; so, likewise, hydrated ferric oxide, and the peculiar ferr
ferric hydrate) discovered by Péan de St.-Gilles (p. 395), and
hydrate (ii. 949). The several varieties of Prussian blue (ii. 229,
soluble by dialysing their solutions in oxalate of ammonium, the lat
away. Stannic and metastannic acids both give soluble m
dialysed from alkaline solutions; titanic acid, when dialysed from a
hydrochloric acid; tungstic acid and molybdic acids, when t
molybdate of sodium in dilute solution are repeatedly dialysed with
hydrochloric acid. (Chem. Soc. J. [2] ii. 318.)

A solution of gum-arabic (gummate of calcium) dialysed after a
chloric acid, gave at once the pure gummic acid of Frémy (ii. 955).
is obtained in a state of purity by dialysing albumin with addition o

Caramel of sugar purified by repeated precipitation with alcoh
by dialysis, contains the proportion of carbon in the highest of the c
Gélis (ii. 748); it forms a tremulous jelly when concentrated, and
colloïdal. Like all other colloïds, it has a soluble and an insoluble m
latter has its solubility restored by the action of alkalis, followed by
and subsequent dialysis.

For further details on the preparation of colloïds by dialysis, see
243—260; also the descriptions of the several substances in their
in this Dictionary.

Separation of Arsenious Acid from Colloïdal Liquids.—Dialysis m
ously applied to the separation of arsenious acid and metallic s
solutions in medico-legal enquiries. The process has the advantage
metallic substance or chemical reagent of any kind into the org
arrangement for operating is also of the simplest nature.

The organic liquid is placed, to the depth of half an inch, on a dia
hoop of gutta percha 10 or 12 inches in diameter, covered with parchme
p. 716). The dialyser is then floated in a basin containing a volum
four times greater than the volume of organic fluid in the dialyser.
basin is generally found to remain colourless after the lapse of 24
being concentrated by evaporation, it admits of the application of th
to precipitate and remove a metal from solution. One-half to thr
crystalloïdal and diffusible constituents of the organic liquid will gene
the water of the basin.

Tartar-emetic and strychnine may be separated from visci
in a similar manner: indeed, all soluble poisonous substances appear
and therefore pass through colloïdal septa.

LIQUIDS, DISPERSIVE POWERS OF. See LIGHT (p. 62

LIQUIDS, EXPANSION OF. See HEAT (p. 52).

LIQUIDS, INDICES OF REFRACTION OF. See LIGHT

LIQUIDS, OSMOSE OF. When two liquids are separated
tion of a porous diaphragm, a flow of liquid takes place from one si
to the other, or sometimes an unequal flow of the two liquids in op
so that the quantity of liquid increases on one side of the septum a
the other. This phenomenon was originally designated by the corre
dosmose and Exosmose, but it is better expressed by the shorter
from ὠσμός, impulsion), which includes the two former.

The passage of liquids through porous septa was first studied by Du
apparatus, called an *endosmometer*, consisted of a narrow glass tube,
shaped expansion at the bottom, and closed at that end by a piece o
tube was filled with a saline solution, and placed in a vertical position
ing water. The flow of liquid in the one direction or the other was
rise or fall of the liquid in the tube. Dutrochet inferred, from his expe
velocity of the osmotic current is proportionate to the quantity of s
substance originally contained in the saline solution. The experimen
inexact, because no allowance was made for the alteration of hyd
caused by the rise or fall of the liquid in the tube. Vierordt (Pogg.

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Dutrochet's apparatus, in which this source of error was city of the current increases with the initial concentration r ratio.

berg, has examined the osmose of water and saline solu- The saline solution containing a known quantity of salt losed at the bottom with bladder, and plunged into water, so as to keep it nearly pure. The tube with its contents ie and weighed, and these operations are repeated till the owing that the whole of the salt has passed out from the remains.

that a given quantity of any salt which passes through is always replaced by a definite quantity of water. The nus replaced by a unit of weight of the salt, is called the *alent* of that salt. This quantity varies with the nature mperature, increasing as the temperature rises; but it is f the solution. At temperatures near 0° C., the endos- of potassium was found to be 200; of chloride of sodium, phate of sodium, between 11 and 12; of neutral sulphate lphate of potassium, 2·3; and of hydrated sulphuric acid

conclusion, that the osmose between water and saline solu- osite passage of two liquid currents, but in the passage e direction, and of pure water in the other. This conclu- ham's observation, that common salt diffuses into water, ox-bladder deprived of its outer muscular coating, at the ane is interposed.

ie saline solution is the only one of the two movements bed as a current. This is, in fact, the true osmose, and action of the membrane or other porous septum; for the is passes into the solution is often much greater than re liquid diffusion, amounting in some cases to several lt displaced.

has been explained in various ways. By Dutrochet and apillarity; but this force is quite insufficient to account for sion which different liquids exhibit in the osmotic appa- nown, that solutions of the most different character exhibit n tubes of equal diameter.

attributed to the unequal absorption of the two liquids by e the septum to be of such a nature as to absorb only one instance. The water will then penetrate the septum, and aline solution, will diffuse into it. More water will then ly diffused, and thus a continuous current will be set up. by the septum, but in different degrees, and each is capable ike water and alcohol, the result will be the formation of osite directions. Water is absorbed by animal membrane st other liquids, and accordingly, when a septum of this f the current is in most cases from the water to the other , a given weight of dried ox-bladder absorbs in the same vols. of a saturated solution of common salt, 38 vols. of 4 per cent., and 17 vols. of bone-oil. When water and nimal membrane, the quantity of water which passes into he quantity of alcohol which passes into the water; but ivided by a thin film of collodion, which absorbs alcohol contrary effect is produced.

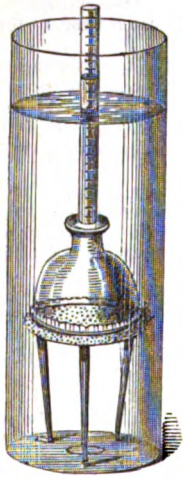
umerous experiments recently made by Graham (Phil. . Soc. J. viii. 43) lead to the conclusion that osmose emical action of the liquid on the septum. These expe- ith porous mineral septa, partly with animal membrane. consisted of the porous cylinders employed in voltaic n depth, surmounted by a glass tube 0· inch in diameter, the cylinder by means of a cap of gutta percha. The e of the glass tube with a saline solution, and immediately ater; and as the liquid within the instrument rose during dded to the jar to equalise the pressure. The rise (or fall) as very regular, as observed from hour to hour, and the rminated in five hours. From experiments made on solu- able substance, it appeared that the rise or osmose is quite

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insignificant with neutral organic substances in general, such as su
tannin, &c.; so likewise with neutral salts of the earths and ordi
the chlorides and nitrates of potassium and sodium, and with chl
A more sensible but still very moderate osmose is exhibited by hy
acetic, sulphurous, citric, and tartaric acids. These are surpassed
mineral acids, such as sulphuric acid, phosphoric, and by sulphate of
are again exceeded by salts of potassium and sodium, possessing
alkaline reaction, such as dioxalate of potassium, phosphate of
carbonates of potassium and sodium. The highly osmotic substance
to act with most advantage in small proportions—producing, in fact, t
in the proportion of one-quarter per cent. dissolved. The same subst
always chemically active bodies, and possess affinities which enable t
material of the earthenware septum. Lime and alumina were always
after osmose, and the corrosion of the septum appeared to be a neces
the flow. Septa of other materials, such as pure carbonate of
compressed charcoal, and tanned sole-leather, although not defi
gave no osmose apparently, because they are not chemically acted
solutions.

Similar results were obtained with septa of animal membrane.
found to act with much greater strength and regularity when div
muscular coat. Cotton calico, impregnated with liquid albumin,
heated to coagulate the albumin, formed an excellent septum, resembl
every respect. The osmometer (*fig.* 714) used

Fig. 714.



ments was arranged like the original instrume
but the membrane was supported by a plate of
and the tube was of considerable diameter, viz.
of the mouth of the bulb, or of the disc of mem
the liquids.

Osmose in membrane presents many poi
to that in earthenware. The membrane is co
ing decomposition, and its osmotic action is ex
and other substances capable of determining a
all chemically active substances, while the great
organic substances and perfectly neutral monob
metals, such as chloride of sodium, possess o
of action, or are wholly inert. The active su
most efficient in small proportions.* With a
ing $\frac{1}{10}$ per cent. of carbonate of potash, the rise
was 167 millimetres; and with 1 per cent. of th
millimetres in five hours. With another
stronger solution, the rise was 863 millimetres,
inches in the same time. To induce osmose, th
on the membrane must be different on the
apparently not in degree only, but in kind,
action on the albuminous substance of the
one side and an acid action on the other. T
always to accumulate on the alkaline or basic
brane. Hence with an alkaline salt, such as carbonate of sodium, i
and water outside, the flow is inwards; but with an acid in the os
negative osmose, or the flow is outwards, the liquid then falling in
chlorides of barium, sodium, and magnesium, and similar neutral salts,
ferent, or appear to act merely in a subordinate manner to some ot
basic substance, which may be present in the solution or the membr
minute quantity. Salts which admit of division into a basic salt and
an osmotic activity of the highest order, *e.g.* the acetate and vario
alumina, ferric oxide and chromic oxide, cuprous chloride, stannous
of lead, &c. The acid travels outwards by diffusion, superinducing
of the inner surface of the membrane, and an acid condition of the
most favourable condition for a high positive osmose. Again, the
potassium and sodium, such as the sulphate and tartrate, though s
properties, begin to exhibit a positive osmose, in consequence, perhap
tion into an acid supersalt and free alkaline base.

The following table exhibits the osmose of substances of all class
brane, the degree being a rise or fall of 1 millimetre:—

* The action increases with the strength of the solution up to a certain point, as
show. With stronger solutions the pores of the membrane probably becomes tou
of salt, and the action consequently diminishes.

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F 1 PER CENT. SOLUTIONS IN MEMBRANE.

	Degrees.		Degrees
.	— 148	Chloride of zinc . . .	+ 54
cent.)	— 92	Chloride of nickel . . .	88
.	— 54	Nitrate of lead . . .	125 to 211
.	— 46	Nitrate of cadmium . . .	137
.	— 30	Nitrate of uranium . .	234 to 458
.	— 3	Nitrate of copper . . .	204
.	+ 2	Chloride of copper . . .	351
.	18	Stannous chloride . . .	289
.	2	Ferrous chloride . . .	435
.	34	Mercuric chloride . . .	121
.	21 to 60	Mercurous nitrate . . .	356
.	14	Mercuric nitrate . . .	476
.	20	Ferric acetate . . .	194
.	21	Acetate of aluminium . .	280 to 393
.	26	Chloride of aluminium . .	540
.	26	Phosphate of sodium . .	311
.	34	Carbonate of potassium . .	439

rbonate of potassium and other alkaline salts is interfered
nanner by the presence of chloride of sodium, being reduced
qual proportion of that salt. The moderate positive osmose
is converted into a very sensible negative osmose by the
e of a strong acid, while the positive osmose of the same salt
small proportion of alkaline carbonate: thus, a 1 per cent.
assium gives an osmose of 21°, but the addition of 0·1 per
sium raises it to between 254 and 204 degrees. (Graham.)
the form of a siphon, and having its shorter leg closed with
with salt water, the shorter leg then immersed in a vessel
poured into the longer leg, so that its pressure may act in
h which the water tends to enter the saline solution through
d that, when the column of mercury attains a certain height,
ithout change of volume, the force of the osmotic current
d by the weight of the mercurial column. In this way the
notic current may be measured. (Liebig.)
an important part in the functions of life. We have seen
ited by dilute saline solutions, such as the animal and
nat the acid or alkaline property which these juices possess is
on for their action on membrane. The natural excitation
of the membranes or cell-walls dividing such solutions seems

remarkably direct substitution of one of the great forces of
another force,—the conversion, namely, of chemical action
iewed in this light, the osmotic injection of fluids may,
nt link which intervenes between chemical decomposition
The ascent of the sap in plants appears to depend upon a
nical, or, at least, molecular action into mechanical force.
nstantly permeating the coatings of the superficial vessels in
s; and as these evaporate into the air, a fresh portion of
membrane and evaporates; and thus a regular upward
which the sap is transferred from the roots to the highest
imilar manner, the evaporation constantly taking place from
als, causes a continuous flow of the animal juices from the
e.
ments on the passage of liquids through colloïdal septa,
vater movement in osmose is an affair of hydration and of
ce of the membrane or other colloïd septum, and that the
ion placed within the osmometer has little or nothing to do
erwise than as it affects the state of hydration of the septum.
siderable through membranous and other highly hydrated
any colloïd (gum, for instance) contained in the osmometer.
of the colloïd is always minute, and may sometimes amount
nsoluble colloïd, such as gum-tragacanth, placed in powder
found to indicate the rapid entrance of water, to convert
atinous hydrate. Here no outward or double movement is

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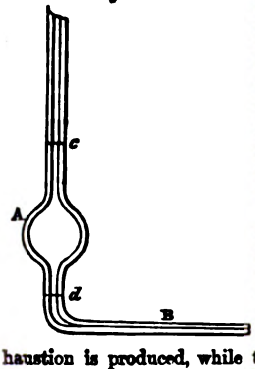
The degree of hydration of any gelatinous body is much affecte medium in which it is placed. This is very obvious in fibrin and an Placed in pure water, such colloïds are hydrated to a higher degree t neutral saline solutions. Hence the equilibrium of hydration is diffe sides of the membrane of an osmometer. The outer surface of the me contact with pure water, tends to hydrate itself in a higher degree surface does, the latter surface being supposed to be in contact with a When the full hydration of the outer surface extends through the membrane and reaches the inner surface, it there receives a check. The tion is lowered, and water must be given up by the inner layer of the it forms the osmose. The contact of the saline fluid is thus attended catalysis of the gelatinous hydrate, by which it is resolved into a lowe drate and free water. The inner surface of the membrane of the osm by contact with the saline solution, while the outer surface dilates by c water. Far from promoting this separation of water, the diffusion of t out the substance of the membrane appears to impede osmose, by equ dition as to saline matter of the membrane through its whole thickne tage which colloïdal solutions have in inducing osmose, appears to depe the low diffusibility of such solutions, and their want of power t colloïdal septum.

The substances fibrin, albumin, and animal membrane swell greatly in water containing minute proportions of acid or of alkali, as is well k other hand, when the proportion of acid or alkali is carried beyond a p each substance, contraction of the colloïd takes place. Such colloïd named, acquire the power of combining with an increased proportion forming superior gelatinous hydrates, in consequence of contact with alkaline reagents. Even parchment-paper is more elongated in an a than in pure water. When so hydrated and dilated, the colloïds pre osmotic sensibility. Used as septa, they appear to assume or resign gelatination under influences apparently the most feeble. It is not atte this varying hydration of colloïds with the osmotic effects thence phenomena belong to colloïdal chemistry, where the prevailing changes appear to be of the kind vaguely described as catalytic. To the futu of catalytic affinity, therefore, must we look for the further elucida (Graham, Chem. Soc. J. xv. 268.)

LIQUIDS, TRANSPIRATION OF. (Poiseuille, Ann. C 50; xxi. 76; Jahresber. 1847–8, p. 139; Graham, Phil. Trans. 1861, Soc. J. xv. 427.)—This term is applied to the passage of liquids th tubes under pressure, in accordance with the analogy of gaseous transpi The first experiments on the subject were made by Poiseuille, who manner in which the flow of the liquid is related to the pressure, an and diameter of the tubes; also, in many cases, the manner in which the nature of the liquid. Graham's enquiries were directed chiefly between the rate of transpiration and the chemical composition of the l

The apparatus used by both these enquirers consists essentially of a stout glass bulb, A (*fig.* 715), about two-thirds of an inch in diameter, city of from 4 to 8 c. c., blown upon a thick glass tube, with a bore c

Fig. 715.



metres. A scratch *c* is made upon the g and another *d* below the bulb, to indica capacity of the instrument. The lower t right angle to the upper, and a fine ca from 3 to 4 inches in length, is sealed extremity of the tube. The bulb and c mersed in a vessel of water during the secure uniformity of temperature. The to impel the liquid through the capillary i compressed air contained in a large res with a mercurial gauge. The time is not

The liquid may be introduced into th the open upper tube by means of a tube-f more convenient, although requiring a mu to fill the bulb by aspiration through the this view, the compressed air is shut off and the upper tube of the bulb allowed with the receiver of an air-pump instea haustion is produced, while the open end of the capillary is immersed the liquid. The liquid which enters the bulb in this manner is sure

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uld cause obstruction in the capillary during the subsequent twards, while the disconnecting of the bulb from the rest of the se of filling the former, is also avoided.

s of Poiseuille it appears that when a tube exceeds a certain as the diameter increases), the rate of efflux is regulated by

directly as the pressure.

al diameter, the quantities discharged in equal times are in-

length, but different diameters, the rate of efflux is as the fourth

h the tube is made does not appear to influence the result, but id employed exercises a marked effect. The liquids used in s were in most cases aqueous solutions of various bodies, the majority of instances, the flow of the solution was slower ter. All the alkalis occasioned this retardation. In a few in- ration was produced; thus neither nitrate of silver, mercuric n, iodide of iron, nitric, hydriodic, bromic, nor hydrobromic acid nfluence, whilst sulphydric and prussic acids, the nitrates and nd ammonium, and the iodide, bromide, and cyanide of potas- dity of the flow; it is remarkable, however, that concentrated tassium, at temperatures above 60°, and of nitrate of potassium more slowly than distilled water. Strict attention to the tem- e comparisons are made is absolutely necessary; for both with olutions generally, a slight elevation of temperature produces a idity of efflux. Water, for instance, at 45° escapes through as fast as it does at 5°.

herto been traced between the rate of efflux of a liquid and its uidity. The capillarity of alcohol, as well as its density, in- it is diluted with water, whilst its fluidity diminishes; but a of alcohol and water flows out with considerably less than half hol, and with less than a third of that of distilled water. The fore, to a great extent, retards its efflux, and beyond that point um rate of efflux corresponds with that particular mixture of n is attended with the maximum contraction after the admixture

y of a body in water appears to exercise but a secondary influ- iseuille shows it to be highly probable that various solutions, e blood of a living animal, provided they do not cause the luce effects of acceleration and retardation on the capillary cir- vith those which are observed in the same liquids in capillary shown this to be the case, by direct experiment, with iodide of into the veins of the horse; and that when various salts are and the liquids are allowed to flow out through small tubes, on occurs, as in the corresponding cases, with their aqueous

contain the numerical results of Poiseuille's experiments. ed according to the acids, which appear to have the greatest efflux. The letters *A*, *B*, *C*, &c., designate the tubes employed. iameter of the tube, H the pressure, measured by a column of the temperature (centigrade), M the quantity of substance in time of efflux in seconds. The figures printed in the thicker efflux of pure water in each case.

quids through Capillary Tubes. (Poiseuille.)

M.	S.	Substance.	M.	S.
946; H = 1000; °.		*B.* L = 64; D = 0·24946; H = 1000; T = 11·6°.		
0	**568·3**	Iodide of potassium .	10·0	530·4
0·1	567·6	„ „ .	20·0	505·7
0·2	566·7	„ „ .	50·0	474·9
0·4	565·6	Iodide of sodium .	0	**569·5**
0·8	563·5	„ „ . .	0·4	569·6
2·0	557·6	„ „ . .	2·0	569·8

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Flow of Liquids through Capillary Tubes—continued.

Substance.	M.	S.
B. L = 64; D = 0·24946; H = 1000; T = 11·6°.		
Iodide of sodium .	10·0	570·0
„ „ .	20·0	577·1
Iodine . . .	0	**568·3**
„ . . .	sat.	568·7
Iodide of iron . .	0·2	568·2
„ „ . .	10·0	568·5
Bromide of potassium	0·4	565·8
„ „ .	2·0	560·0
„ „ .	10·0	537·6
T = 11·2°.		
Nitrate of potassium .	0	**575·8**
„ „ .	0·1	574·5
„ „ .	0·2	573·5
„ „ .	0·4	571·4
„ „ .	1·0	564·5
„ „ .	10·0	541·2
„ „ .	20·0	533·3
„ of ammonium	1·0	569·4
„ „ .	10·0	531·1
„ of sodium .	1·0	575·9
„ „ .	10·0	592·4
„ of lead . .	1·0	577·8
„ „ . .	4·0	582·9
„ of strontium .	1·0	578·8
„ „ .	4·0	586·7
„ of calcium .	1·0	581·2
„ „ .	10·0	623·6
„ of magnesium	1·0	583·2
„ „ .	10·0	641·7
C. L = 37; D = 0·19495; H = 1370·8; T = 14·2°.		
Nitrate of silver . .	0	**741·5**
„ „ . .	1·0	740·9
„ „ . .	10·0	741·0
B. H = 1000; T = 11·9°.		
		565·0
Chloride of potassium	1·0	560·8
„ „ .	10·0	544·8
„ of ammonium	1·0	560·9
„ „ .	2·0	556·5
„ „ .	10·0	535·8
„ of sodium .	1·0	569·4
„ „ .	10·0	640·3
„ of calcium .	1·0	571·2
„ „ .	10·0	620·7
„ of magnesium	1·0	574·9
„ „ .	10·0	646·8
B. H = 865·1; T = 11·2°.		
Mercuric chloride .	0	**608·5°**
„ „ .	10	608·1
„ „ .	20	607·9
„ „ .	sat.	607·8

Substance.	M.	S.
B. H = 1000; T = 11·2°.		
		575·8
Hydrochlorate of morphine . . .	1·25	589·8
Hydrochlorate of strychnine . .	1·4	590·0
T = 12·7°.		
		554·0
Cyanide of potassium	1·0	551·6
„ „ .	4·0	548·8
„ of mercury .	1·0	558·4
„ „ .	4·0	564·3
	to serum:	
Serum . . .		1014·5
Cyanide of potassium	1·0	998·7
„ of mercury .	1·0	1025·3
T = 11·2°.		
		575·8
Sulphate of potassium	1·0	578·9
„ „ .	4·0	592·1
„ of ammonium	1·0	582·0
„ „ .	4·0	598·9
„ of sodium .	1·0	590·3
„ „ .	4·0	606·1
„ of magnesium	1·0	590·3
„ „ .	4·0	630·1
„ of zinc . .	2·0	595·6
„ of ferrosum .	2·0	609·5
„ of morphine .	1·25	590·3
T = 12·7°.		
		575·8
Alum	1·0	592·4
„ . . .	4·0	632·4
Phosphate of potassium	1·0	583·4
„ „ .	4·0	602·7
„ of sodium .	1·0	588·6
„ „ .	4·0	622·8
„ of ammonium	1·0	590·2
„ „ .	4·0	626·2
T = 11·2°.		
		575·6
Arsenate of potassium	1·0	583·3
„ „ .	2·0	590·8
„ of sodium .	1·0	588·0
„ „ .	4·0	617·3
Acid carbonate of ammonium . . .	1·0	580·6
Acid carbonate of potassium . . .	1·0	580·4
Acid carbonate of sodium . . .	1·0	589·8
Carbonate of ammonium . . .	1·0	583·8
„ „ „	4·0	602·9
Carbonate of potassium	1·0	588·3
„ „ .	4·0	617·0
„ of sodium .	1·0	592·5
„ „ .	4·0	622·7

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Liquids through Capillary Tubes—continued.

M.	S.
.	
	566·2
1·0	571·1
10·0	620·1
1·0	574·2
4·0	596·6
1·0	578·4
1·0	573·4
= 141°.	
	620·0
1·0	633·1
4·0	653·5
= 11·4°.	
	571·0
2·0	595·3
	575·8
1·0	581·2
4·0	594·7
; H = 1998·6;	
	123′ 38″
2·0	122 35
= 11·9°.	
	564·7
2·0	579·4
2·0	611·4
10·0	628·7
pure	725·4
	574·9
1·0	575·0
4·0	574·5
1·0	573·9
3·2	574·6
8·2	573·3
	566·2
1·0	570·1
3·4	573·5

Substance.	M.	S.
E. L = 27; D = 0·1316; H = 2012·2; T = 10°.		
		499·0
Prussic acid . .	33·3	489·0
F. L = 70; D = 0·207; H = 2 039·4; T = 10°.		
Pure serum		1448
100 water to 100 serum . .		1277
100 prussic acid „ . .		1278
100 sulphydric acid „ . .		1266
B. H = 1000; T = 11·6°.		
		568·3
Hydrobromic acid .	1·0	569·7
„ „ .	7·2	571·4
Bromic acid . .	1·0	569·3
„ „ . .	3·2	570·5
T = 11·2°.		
		575·8
Hydrochloric acid .	1·0	577·3
„ „ .	2·0	579·5
„ „ .	10·0	591·8
„ „ .	20·0	604·3
Carbonic acid . .	sat.	580·5
Artificial Seltzer water	sat.	584·2
Solid oxalic acid . .	1·0	582·9
„ „ . .	2·0	590·6
„ „ . .	10·0	625·7
„ phosphoric acid .	1·0	582·8
„ „ „ .	4·0	603·9
Acetic acid . . .	1·0	585·5
„ . . .	10·0	633·4
„ . . .	pure	1315·0
Solid citric acid . .	1·0	586·0
„ „ „ . .	10·0	682·1
„ arsenic acid .	1·0	586·3
„ „ . .	4·0	618·0
Arsenious acid . .	1·0	578·6
Concentrated sulphuric acid . . .	1·0	589·6
Concent. sulphuric acid	pure	1459·5
Solid tartaric acid .	2·0	601·1
Serum of ox-blood .	pure	1048·5
Madeira wine . .	„	1134·1
Sparkling Sillery .	„	1462·8
Jamaica rum . .	„	1831·9

n that the flow of a liquid is greatly retarded by the pre-
of a soluble colloïd; so much so that the transpiration tube
scope. The transpirability of different salts appear also
io of diffusibility in water.
ed by Poiseuille that aqueous alcohol has a point of
ident with the degree of dilution at which the greatest con-

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densation of the mixed liquids occurs,—which degree of dilution corr
hydrate, $C^2H^6O.3H^2O$, has been made by Graham the starting-point
series of experiments on the relation between capillary transpiratio
composition. The 3-atom hydrate of methylic alcohol, $CH^4O.3$
distinguished by any particular degree of condensation in volume, exhi
in its transpiration rate, similar to that of dilute ethylic alcohol. The h
also, in many cases, exhibit a characteristic retardation of transpiratio
degree of hydration. In hydrated substances generally, the extent to
tion is affected by annexation of water, is by no means in proportion t
combination. In sulphuric acid, for instance, the maximum t
occurs with the hydrate $H^2SO^4.H^2O$; in acetic acid, with the compou
of nitric acid with $2HNO^3.3H^2O$; and with alcohol, as above ol
hydrate $C^2H^6O.3H^2O$. The transpiration-times of these hydrates ar
other results, in the following table, in which the transpiration-time
same temperature is taken as the unit of comparison:

Transpiration-times of Acids, Alcohols, and Ethers. (Gra

Liquid (undiluted).		Transpiration-time.	Degree hydrati
Water		1·0000	
Methylic alcohol	CH^4O	0·6300	+ 3H
Ethylic alcohol	C^2H^6O	1·1950	+ 3H
Amylic alcohol	$C^5H^{12}O$	3·6490	
Formate of ethyl	$C^3H^6O^2$	0·5110	
Acetate of ethyl	$C^4H^8O^2$	0·5530	
Butyrate of ethyl	$C^6H^{12}O^2$	0·7500	
Valerate of ethyl	$C^7H^{14}O^2$	0·8270	
Acetic acid	$C^2H^4O^2$	1·2801	+ H
Butyric acid	$C^4H^8O^2$	1·5650	+ H
Valerianic acid	$C^5H^{10}O^2$	2·1550	+ H
Nitric acid	NHO^3	0·9899	+ $\frac{2}{3}$H
Sulphuric acid	SH^2O^4	21·6514	+ H
Acetone	C^3H^6O	0·4010	+ 6H

On comparing the transpiration-times of the several alcohols, eth
this table, it will be seen that, so far as these observations extend, th
sion of individual substances in any homologous series is indicated b
transpirability as clearly as by their comparative volatility, the h
having the slowest rate of efflux. It may also be observed that the t
of an acid is slower than that of an ether with which it is metameric;
example, is slower than acetate of ethyl.

LIQUORICE. See Glycyrrhizin (ii. 920).

LIRIODENDRIN. A neutral substance, existing, according
stem of the tulip-tree (*Liriodendron tulipifera*). It is obtained b
bark with water, concentrating to one-fifth, washing the impure
separates with weak potash, and crystallising from boiling dilute
tallises in scales or in radiating needles. It is bitter, melts at 83°,
sparingly soluble in water, very soluble in alcohol and ether. It i
strong hydrochloric or sulphuric acid, the latter converting it int
Iodine colours it yellow.

LIROCONITE. *Octahedral Arsenate of Copper, Chalcophac*
This mineral occurs in trimetric crystals, exhibiting the combination
sionally an inch in diameter, but usually minute. Angle ∞P :
$P\infty$: $P\infty = 72° 22'$. Cleavage lateral, but obtained with difficulty.
Hardness = 2 to 2·5. Specific gravity = 2·882 to 2·985. Lustre vitr
resinous. Colour and streak sky-blue. Fracture imperfectly con
Imperfectly sectile.

When heated it turns green and begins to glow, then becoming d
charcoal before the blow-pipe it melts slowly, and forms a red bri
reduced with carbonate of sodium, it yields white scales of ars
(Damour). It is completely dissolved by acids, and even by ammon

The following are analyses of liroconite from Cornwall; *a.* by H
Chem. xxxiii. 296)—*b.* by Damour (Ann. Ch. Phys. [3] xiii. 404)
Wachtmeister (Kongl. Vet. Acad. Förhandl. 1832, p. 80):—

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O^5	CuO	Al^2O^3	H^2O		
73	36·38	10·85	25·01	=	99·02
24	37·40	10·09	25·44	=	98·57
98	39·16	8·94	25·78	=	100·00

esented by the following formulæ:

$4Al^2O^3.P^2O^5).3(5CuO.As^2O^5).48H^2O$
$4Al^2O^3.P^2O^5).4(5CuO.As^2O^5).60H^2O$
$4Al^2O^3.P^2O^5).5(5CuO.As^2O^5).72H^2O$

rious ores of copper, pyrites, and quartz, at Huel Gorland
; also in minute crystals at Herrengrund in Hungary, and
29.)

n. with Heavy Spar.

ight 7, *Symbol*, Li.—Lithia, the oxide of this metal, was
1817. It was first obtained from petalite (silicate of alu-
nich it exists to the amount of 5 per cent.; it exists also
ent.), amblygonite (11 per cent.), triphyline (3·4 per cent.),
pyrite, and the tourmaline of Uton in Sweden. The most
yet discovered is a mineral spring in Cornwall, analysed by
the British Association, 1864). In smaller quantities it is
found in sea-water, in many micas and felspars, in the ash
in sea-water, and in many mineral springs.—Bunsen has
eorite of Juvenas in France, and in that of Parnallee in
. Pharm. cxx. 253), and Engelbach has found it in the
gg. Ann. cxvi. 512.)
nalen, viii. 120) stated that a white combustible metal is
e action of the electric current, but metallic lithium was
m by Bunsen (Pogg. Ann. xciv. 107). The process is as

is fused over a spirit-lamp in a small porcelain crucible,
arbon battery of 4 to 6 cells. The positive pole is a small
rd carbon deposited in gas-retorts), and the negative pole
kness of a knitting-needle. After a few seconds, a small
ed under the fused chloride, round the iron wire and
vo or three minutes attains the size of a small pea. To
ole and regulus are lifted out of the fused mass, by a small,
ila. The wire may then be withdrawn from the still melted
m oxidation by a coating of chloride of lithium. The metal
from the spatula with a pen-knife, after having been cooled
rations may be repeated every three minutes; and thus an
be reduced in a very short time.
surface, has the colour of silver, but quickly tarnishes on
ng slightly yellow. It melts at 180°, and if pressed at that
lass plates, exhibits the colour and brightness of polished
tassium or sodium, but softer than lead, and may, like that
ire. It tears much more easily than a lead wire of the same
velded by pressure at ordinary temperatures. It floats on
st of all known solids, its specific gravity being 0·589—

idable than potassium or sodium. It makes a lead-grey
s at a temperature much higher than its melting point,
an intense white light. It burns when heated in oxygen,
r carbonic anhydride, and with great brilliancy on boiling
water, it oxidises, but does not fuse like sodium. Nitric acid
t melts and often takes fire. Strong sulphuric acid attacks it
id and hydrochloric acid quickly. Silica, glass, and porce-
um at temperatures below 200°. (Bunsen, Ann. Ch.

IDE OF. LiCl. Produced when lithium burns in chlorine
hia or carbonate of lithium in hydrochloric acid. By evapo
at temperatures above 15·5°, or an alcoholic solution over
us chloride is obtained in cubes having the taste of common
ng to Troost, it crystallises in regular octahedrons. According
atile than chloride of potassium, less volatile than chloride
els it volatilises even below a red heat, and is partially con-

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The *hydrated chloride*, LiCl.H²O according to Rammelsberg, LiCl. to Hermann and Troost, is formed when the anhydrous chloride deliqu or when the aqueous solution is evaporated at a rather low temperatu and crystallises in large rectangular prisms with four-sided summit lateral edges: it is probably isomorphous with hydrated chloride of sod crystallisation, it forms needles grouped in feathery tufts like (Hermann). Both the anhydrous and the hydrated chloride deliquesc air, and dissolve very readily in water and in alcohol. (C. Gmelin.)

LITHIUM, DETECTION AND ESTIMATION OF. 1. *the dry way.*—Lithium salts are white, excepting those which contain such as chromic acid. They are more readily fusible than the corres potassium and sodium, and are permanent in the fire, if the acid is no easily decomposed. Fused with *carbonate of sodium* on platinum a dark yellow stain round the circumference, whilst carbonate of sodiu luces this effect to a much smaller degree only (Berzelius). Fus wire they colour the blowpipe flame carmine-red. An excess of a pota not interfere with the production of this colour, but the presence of a of soda gives rise to the yellow flame (H. Rose). Alcohol, in which a is dissolved or diffused in the state of fine powder, also burns with flame (C. Gmelin). The same occurs also with paper saturated of a salt of lithium, or the wick of a taper saturated with moistened ph tate of lithium (Turner, Ed. Phil. J. of Sc. ii. 267; iv. 113). By spectroscope, the occurrence of very minute traces of lithium may be brilliant crimson band, having a refrangibility between those of the lines solar spectrum, and a faint yellow band somewhat less refrangible than these two lines the whole light of the lithium spectrum is contained, w the gas-flame of a Bunsen's burner. At very high temperatures, howev of a hydrogen-flame, a blue line also makes its appearance.

2. *Reactions in Solution.*—All salts of lithium are soluble in carbonate and phosphate, and the double phosphate of lithium and s slightly soluble. Hence the other salts of lithium, when not dissolve water, yield difficultly soluble precipitates with *carbonate of ammonium sodium*, and with *phosphate of sodium*. *Carbonate of sodium* precipita lithium after some time only. Common *disodic phosphate* does not prec the cold, even after a long time, except on the addition of ammonia, w gives rise to an abundant precipitate. But a mixture of a salt of lithi phate of sodium becomes turbid by boiling or evaporation, and the being treated with water, leaves the difficultly soluble phosphate of lithi

Phosphate of potassium gives no precipitate, even on boiling or evapo the addition of *ammonia*, an abundant precipitate after some time (H. *drofluosilicic acid* throws down from salts of lithium the almost insol silicium and lithium (Berzelius), and *picric acid* precipitates picrate Rose). Solutions of lithium-salts, even when concentrated, are not perchloric acid, sulphate of aluminium, dichloride of platinum, oxalic a acid.

A solution of a salt, which is not clouded by caustic soda in the col nate of sodium at a boiling heat, but yields with phosphate of sodium, an almost insoluble white powder, contains lithia. (Berzelius.)

3. *Quantitative Estimation and Separation.*—Lithium, after s other metals, may be estimated as carbonate, sulphate, or chloride. The h organic salts of lithium are converted into carbonate, Li^2CO^3, when ign with the air. All lithium-salts containing volatile acids, may be conv phate by heating them with sulphuric acid: the excess of acid may simple ignition, without addition of carbonate of ammonia, because lit form an acid sulphate. The chloride is not so well adapted for quantitat as the sulphate, on account of its hygroscopic qualities; but as lithiu obtained as chloride, in the process of separating it from sodium, it is estimate it directly in this form: it must be ignited in a well-covered weighed immediately after cooling.

Lithium may also be estimated as phosphate, Li^3PO^4, by evaporating a lithium-salt with phosphate of sodium, adding a quantity of hydrate sodium sufficient to keep the liquid alkaline; digesting the residue and washing the precipitate with a mixture of equal volumes of water then drying at 100°, and igniting. The determination may be render by repeatedly evaporating the filtrate and wash-water, and treating the s of lithium-phosphate thereby separated, as before (W. Mayer, Ann xcviii. 193; Jahresb. 1856, p. 739). According to Rammelsberg (

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olutions of lithium treated with phosphate and carbonate
rm M^3PO^4, containing variable quantities of lithium and
itschr. Annal. Chem. i. 42) finds that the precipitate ob-
he composition Li^3PO^4, and, accordingly, that Mayer's
correct results.

the earth-metals and heavy metals in the same
namely, by sulphydric acid, sulphide of ammonium, or
From potassium it may be separated by *dichloride of*
otassium, but not lithium; and from sodium, by con-
chlorides, and treating the dried chlorides, in a well
of *ether* and *absolute alcohol*, which, in the course of a
e of lithium, and leaves the chloride of sodium.

ss is somewhat tedious, and is apt to be rendered inexact
Bunsen (Ann. Ch. Pharm. cxxii. 348) recommends the
stimating lithium, when it exists in the state of mixture
ali-metals. The anhydrous mixture of the chlorides of
y exhausted with ether-alcohol; the residue obtained by
gain treated in the same manner; and the evaporated
ted and weighed. It is then dissolved in water; the
letermined by precipitation with nitrate of silver; the
ss of silver by hydrochloric acid, and the potassium con-
chloride of platinum. The quantity of chloride of potas-
hen deducted from the total weight of the chlorides, a
lithium + y chloride of sodium; and the quantity of
the known quantity of chloride of potassium, gives, when
of the chloride of silver, a weight B, whence the quan-
alculated by the formula—

$$x = 1{\cdot}0823\ B - 2{\cdot}6525\ A.$$

thium. The earlier determinations of this number by
Gmelin, and Kralovansky, were much too high, having
containing sodium. Hermann, Berzelius, and Hagen,
n free from sodium by precipitation with carbonate of
inte sulphate, which was then analysed by precipitation
Berzelius obtained the number 6·5. The numbers ob-
n were lower, and even that of Berzelius has been shown
o be too low, the error probably arising from partial
e of lithium during fusion.
. 349), by decomposing chloride of lithium with nitrate
s 6·92 and 6·96. Diehl (Ann. Ch. Pharm. cxxi. 93),
of lithium, the purity of which had been tested by
omic weight of the metal = 7·026. Troost (*ibid.* cxxiii.
carbonate with silicic acid, obtained the number 7·01;
ave the same result; and the decomposition of the car-
ded the number 7·06. From all these results, the num-
omic weight of lithium.

E OF. This compound crystallises from the aqueous
e grains, which, at the temperature of commencing red-
ain becoming cloudy as it solidifies. It is very slightly
s.)

F. *Lithia*, Li^2O.—*Anhydrous lithia* is obtained as a
containing a certain quantity of peroxide, by burning
the product to cool in a stream of the gas. (Troost,

ined from petalite, spodumene, or lepidolite, which are
ost advantageously from lepidolite), or from triphyline,
um, manganese, iron and aluminium, by the following

thia-spodumene, reduced to fine powder by careful levi-
s weight of quicklime; the mass is treated with hydro-
ric acid; the resulting sulphate of lithium is dissolved
um; and the last traces of calcium are removed by pre-
mmonium. The solution of sulphate of lithium is then
aryta-water just sufficient to throw down the sulphuric
ration yields hydrate of lithium.
. [3] li. 121) heats 10 pts. of finely-powdered lepidolite

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with 10 pts. of carbonate of barium, 5 pts. sulphate of barium, and 3 potassium. The fused mass separates on cooling into a heavy transp supernatant white crystalline slag, consisting of the sulphates of potassium, and sodium, and containing nearly all the lithium. The are dissolved out by water, and converted into chlorides by chlorid potassium is precipitated by chloride of platinum, and the chlorid sodium are separated by means of alcohol and ether. In operating the double sulphate of lithium and potassium may be separated l tallisation.

3. Triphyline is dissolved in strong hydrochloric acid, nitric ac bring the iron to the state of ferric oxide; the solution is evaporate the residue is treated with water, which leaves all the iron as ins The solution containing the chlorides of lithium and manganese phoric acid, is treated with sulphide of barium, which removes t stances; the excess of barium is removed by sulphuric acid (or bette ammonium), and the filtrate is evaporated to dryness and ignited. C thus obtained frequently contains chloride of sodium, which may alcohol and ether. The chloride is then converted into sulphate, a caustic lithia is obtained as above. (Müller, Ann. Ch. Phys. [3] xl

Hydrate of Lithium, LiHO, separates from the aqueous solution i grains. It has the same taste, causticity, and alkaline action on veg potash and soda, but is much less soluble in water. It melts eas forming a fused mass which has a crystalline fracture. It does not a at a white heat.

Fused lithia, as commonly prepared, corrodes platinum vessels p silver vessels should always be used for heating it. This action upo indeed, to be one of the best indications of the presence of lithium; Troost (Ann. Ch. Pharm. cxxiii. 384), it is not produced by pure pure lithium-salt, but only by such as contain cæsium and rubidium

Peroxide of Lithium is said by Troost to be formed, together lithium is burned in oxygen gas.

LITHIUM, SULPHIDE OF. Li^2S. This compound is for is thrown on melted sulphur; also when sulphate of lithium is heat charcoal. It dissolves in water and alcohol more easily than lithia.

LITHOGRAPHY. See PRINTING, CHEMICAL.

LITHOMARGE. *Stone-marrow* (*Steinmark*). A kind of cla are two varieties, the friable and the indurated.

Friable Lithomarge.—Colour white. Massive and sometimes in scaly and feebly glimmering; streak shining. Slightly cohering Feels rather greasy; adheres to the tongue. Light. Phosphoresces constituents are, according to Klaproth, silica 32, alumina 26·5, ir sodium 1·5, and water 17·0. It occurs sometimes in tin-stone veins

Indurated Lithomarge. Colours yellowish and reddish-white. M daloïdal. Dull, opaque. Fracture fine earthy. Streak shiny. easily frangible; adheres strongly to the tongue; greasy to the touch 2·44. Infusible before the blowpipe. Some varieties phosphoresce, moistened, afford an agreeable smell like that of nuts. Its cons 45·25, alumina 36·5, oxide of iron 2·75, water 14, and a trace of pot It occurs in veins in porphyry, gneiss, &c., at Rochlitz in Saxon (Jameson.)

LITHOSPERMUM. The root-bark of *Lithospermum arven* colouring matter, which reacts with water, alcohol, ether, and alkali as that of alkanet (i. 128), excepting that the lithosperm-red form with ether, whereas alkanet-red forms a dark red solution. (Ludwig Rép. Chim. app. 1859, p. 211.)

LITMUS. *Lackmus. Tournesol en pains.*—A blue colouring m for preparing test-papers. It is obtained from various species of *Ro* and *Lecanora*, the same lichens in fact that yield archil (i. 355). I experiments of Gélis (Revue Scient. vi. 50) that the blue co developed in the lichens by fermentation, when the proximate prin them are metamorphosed in presence of an alkaline carbonate. Un the air and ammonia alone, these lichens yield nothing but archil; carbonate is likewise present, the lichens undergo a totally different product of the fermentation, instead of being red or violet, has then This blue coloration is due to the combination of the new colourin

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known, redden litmus, that is to say, they unite with the
ring matter of the litmus, which in this state is red, like
of *Roccella tinctoria* and 1 pt. carbonate of potassium are
rbonate of ammonium, or with urine which is saturated
uires in three days a brown or dirty red colour; in 20
30 days a blue colour; and in 40 days yields litmus of the
rm. xxiv. 277). Litmus is prepared in Holland from
ella tinctoria from the Canary Isles, the coloured mass
kened with chalk or gypsum.

ouring matters of litmus is not very exact, but they are
m orcin, like orceïn, the colouring principle of archil. The
g matters is azolitmin, and three others have been
iolitmin, erythrolein, and erythrolitmin. The
ion of these colouring matters is given by Kane (Phil.

powder is exhausted with boiling water, and the pale blue
greater part of the colouring matter, is made up into a thin
ochloric acid is added till effervescence ceases and the
line reaction. The mass is then thrown on a filter; and
l from excess of acid by washing with water, is well dried
lcohol, as long as that liquid extracts anything from it.
porated to dryness over the water-bath, and the residue
long as the ether is coloured by it. The ethereal solution,
o remove the ether, leaves Erythrolein in the form of a
portion of the alcoholic extract which is insoluble in ether
.

which remains after the boiling with alcohol (*vid. sup.*)
in. This substance is either boiled with pure water, and
evaporating the strongly coloured solution; — or the
l is boiled with ammoniacal water, and the blue solu-
luring which operation the greater part of the ammonia
parated by moistening the mass with hydrochloric acid, and
monia with alcohol.

iquid obtained by boiling litmus with water is precipitated
l; the precipitate washed with water, treated while still
and suspended in warm ammoniacal water; the dark blue
yness, and moistened with hydrochloric acid; and the
y means of warm alcohol. The residue is but of small
the deep colour of the solution; it sometimes consists
rarely of Spaniolitmin, a substance not containing

amorphous powder which dissolves with blue colour in
d violet lakes.

n obtained mixed with azolitmin, but it appears to be of a

l mass of a fine red colour, and dissolves in ammonia,

talline grains of a fine deep red colour, coloured blue
h ammonia, a blue compound insoluble in water.

nalytical results obtained by Kane with these substances,
atomic weight of carbon (6·12 or 12·24):

rolein.	Erythrolimin.		Azolitmin.		Spaniolitmin.
4·27	55·78	55·3	49·50	50·05	44·54
0·68	8·69	8·1	5·35	5·52	3·11

zolitmin is the only one which contains nitrogen. Kane
ly by the comparative method which gave proportions of
3 to 1 : 18·3.

tmin approaches pretty nearly to the formula $C^7H^7NO^4$
nitrogen 8·2), according to which azolitmin would contain
n, and might be derived from orcin in the manner shown by

$$C^7H^8O^4 + NH^3 + O^3 = C^7H^7NO^4 + H^2O.$$

of the alkaline carbonates in the formation of litmus may
hat these salts accelerate the absorption of oxygen by orcin
f air and ammonia, so as to produce a new compound more
ïn.

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The ammoniacal solution of azolitmin forms with the salts of the he tates which are red or blue, according to the quantity of metal contai azolitmates of *barium* and *calcium* are blue. The *lead-compound* violet colour when recently prepared, but becomes blue when drie to contain $2C^7H^6PbNO^4.Pb^2O$. The *stannous salt* is a lake of a fi exposure to the air in the moist state it is converted into a *stan* splendid scarlet colour.

Azolitmin suspended in water through which chlorine gas is p chlorazolitmin.

Azolitmin subjected to the action of nascent hydrogen, is disso into a compound called by Kane, leucazolitmin, which, however pure, because it oxidises immediately and becomes coloured when A white compound of leucazolitmin with stannic oxide is form stannous compound of azolitmin with water; on exposure to the ai converted into the scarlet stannic compound of azolitmin.

LIVER, GLYCOGENIC FUNCTION OF. See Glycog

LIVER OF SULPHUR. An old term applied to a mix sulphides of potassium, obtained by heating sulphur with carbonat covered vessel. (See Potassium, Sulphides of.)

LIXIVIATION. The application of water to the fixed resid purpose of extracting the saline part.

LIXIVIUM. A solution obtained by lixiviation.

LOADSTONE. Magnetic iron ore (p. 397): see also Magn

LOAM. See Clay (i. 1023).

LOBELINE. An alkaloïd existing, according to Bastick and J. Trans. x. 270, 456) in *Lobelia inflata*. It is oily; cannot be decomposition; dissolves very readily in water, alcohol, and ether lisable salts with hydrochloric, sulphuric, nitric, and oxalic acids. precipitated by tannin. It acts as a narcotic when taken internally

LOBOITE. A magnesian vesuvian from Norway. (See Vesuv

LOELINGITE. Syn. with Leucopyrite (p. 585).

LOEWITE. A sulphate of magnesium and sodium, Mg^7Na^2 Ischl, approaching astrachanite in composition. It is of yellow gravity 2·376, and gives by analysis 52·35 SO^3, 12·78 MgO, 18·2 and 0·66 Fe^2O^3 and Al^2O^3 = 99·21. (Karafiat, Haid. Ber. 1846,

LOGANITE. A variety of pyrosclerite from Calumet Isla Canada, where it occurs associated with serpentine, phlogopite, p in crystalline limestone. It has a weak subresinous lustre, pale colour, and greyish streak. Hardness = 3. Specific gravity = 2·6 in crystals with rounded angles, which appear to be pseudomor angle 124°, near that of hornblende. Contains 32·49 per cent. sil 35·77 magnesia, 0·95 lime, 2·14 protoxide of iron, and 16·92 water acid) = 101·45. (T. S. Hunt, Phil. Mag. [4] ii. 65.)

LOGWOOD. *Bois de Campèche. Blauhols.*—The tree whic is called by Linnæus, *Hæmatoxylum campechianum*.

Logwood is so heavy as to sink in water, hard, compact, of a fin being polished, and scarcely susceptible of decay. Its predominant with orange, yellow, and black.

It yields its colour both to spirituous and watery solvents. Alcoh readily and copiously than water. The colour of its dye is a fine r to violet or purple, which is principally observable in its watery de to itself, becomes in time yellowish, and at length black. Acids tur deepen its colour, and give it a purple or violet hue.

Stuffs would take only a slight and fading colour from decoction were not previously prepared with alum and tartar. A little alum bath. By these means they acquire a pretty good violet.

A blue colour may be obtained from logwood, by mixing verdigri dipping the cloth till it has acquired the proper shade.

The great consumption of logwood is for blacks, to which it give very cast, and for greys of certain shades. It is also of very extensi compound colours, which it would be difficult to obtain of equal be means of drugs affording a more permanent dye.

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equently mixed with that of brazil-wood, to render colours
g varied according to the shade desired.
g silk violet. For this, the silk must be scoured, alumed,
t aluming, it would take only a reddish tinge that would
ilk thus, it must be turned in a cold decoction of logwood
colour; if the decoction were used hot, the colour would

fine violet might be produced from logwood by impreg-
n of tin. In fact we may thus obtain, particularly by
od in various proportions, a great number of fine shades,
from lilac to violet. See HÆMATOXYLIN (p. 4). U.

h LAUMONTITE (p. 472).

iety of marcasite or white iron pyrites, found at Freiberg,
ll. Hardness = 6·5. Specific gravity = 4·925—5.
greenish or greyish. Streak, black. According to Platt-
61 per cent. S, 4·40 As, 44·23 Fe, 0·35 Co, 0·75 Cu, and
haupt and Plattner, Pogg. Ann. lxxvii. 135.)

ot of *Toddalia aculeata*. By successive treatment with
ilute hydrochloric acid, it yields about 40 per cent. of
a bitter principle, a tasteless resin, gum, tannin, starch,
Weber, Jahresber. 1859, p. 572. See also Schnitzer,

Pyrobenzoline. (Laurent, Ann. Ch. Phys. [3] xix. 369.
n. liv. 365 and 368.—Gössmann, *ibid.* xciii. 331.—
, *ibid.* xcvii. 283; Chem. Soc. J. ix. 220.—Gm. xii. 199.
—An organic base produced by the dry distillation of hy-
e, or azosulphide of benzylene (Laurent), of amarine
sulphite of benzoyl and ammonium with slaked lime
n from hydrobenzamide (p. 183), or from the isomeric
epresented by the equation,

$$= 3C^{21}H^{16}N^2 + C^{21}H^{18} + 2NH^3.$$
de. Lophine. Oil.

C^7H^6 (polymeric with stilbene) is probably the oily matter
phine. (Gerhardt.)
ydrobenzamide is heated, ammonia escapes, together with
ere remains a fused mass which may be distilled at a high
antageously treated by pouring it out, pulverising it when
ether, which extracts a small quantity of a body crystal-
he solution cools. The residue is heated with alcohol to
ustic potash added to it till the whole is dissolved; the
read-like crystals which may be washed with alcohol. It
the residue insoluble in ether, with alcohol containing
olution at the boiling heat with ammonia, and leave it to
the mixture of lophine and amarine obtained by distilling
is extracted by boiling with rock-oil, or the lophine by
ng hydrochloric acid (Laurent).—3. From the distillate
ide of benzylene, the oily products are extracted by ether,
ol, and the thionessal by rock-oil, and the residue, con-
ed by boiling with alcohol and potash, or with alcohol
. A similar process is adopted with the product resulting
obtained by treating bitter-almond oil for two or three
mmonium, which mixture also contains picril (Laurent).
ystals which sublime in the neck of the retort during
f benzoyl and ammonium with hydrate of calcium, are
l recrystallised after being treated with animal charcoal.
ine is facilitated by heating the retort very quickly and
the commencement of the distillation, with red-hot coals
de of conducting the process is to add a quantity of quick-
hydrate, introduce the mixture into a rather shallow glo-
, and cover the retort, as far as it is filled with the mixture,
beginning of the operation. Only small quantities should
10 to 15 grms. of the benzoyl-compound, with about 4 to
lime mixture. When the operation is thus conducted, only
forms at first; and when this has melted down, the upper

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part of the retort begins to be covered with radiant masses of lophin tion of secondary products ceases, nothing being formed but lophine a At the commencement, a small quantity of an aromatic oil accomp apparently resulting from the decomposition of the amarine into l products, the principal of which is amarone (Gössmann and Atk cation as in Laurent's method (1).

Properties.—Lophine forms colourless needles, often an inch long, and having a lustre similar to that of caffeine; they become opales but retain their lustre. At 250° the compound sublimes, gradually without previous fusion, and without decomposition. It melts at transparent liquid, which at 260° solidifies in a radiating crystalline less and inodorous, with scarcely any alkaline reaction. The alcoholic fluorescence like quinine, but not in so high a degree. It has no act light (Gössmann and Atkinson). G. Kühn (Chem. Centr. 1 tained, by the dry distillation of hydrochlorate of hydrobenzamid modifications of lophine, one crystallising in needles which melted (likewise obtained by Ekman, Ann. Ch. Pharm. cxii. 151) in need at 170°.

The composition of lophine has been variously represented by the and $C^{28}H^{16}N^2$ (Laurent), $C^{21}H^{16}N^2$ (Fownes), $C^{21}H^{17}N^2$ (Gössma son), $C^{28}H^{16}N^2$ (Lisst). Fownes's formula, $C^{21}H^{16}N^2$, agrees best, o the analyses, and likewise affords the best representation of the form pound from hydrobenzamide (or from amarine):

	Calculation.		Laurent.		Fownes.	Gössman
C^{21}	252	85·1	85·6	86·0	85·2	85·7
H^{16}	16	5·4	5·4	5·1	5·4	5·5
N^2	28	9·5	9·2	· ·	9·1	· ·
$C^{21}H^{16}N^2$	296	100·0	100·2		99·7	

Laurent's second analysis, which differs considerably from all the made with impure material.

Lophine is insoluble in *water*, very sparingly soluble in boiling crystallising in needles on cooling. It dissolves to about the same a and in *oil of turpentine*, whence it separates in a crystalline powd dissolves easily and without decomposition in boiling *alcoholic potash*.

According to Ekman (Ann. Ch. Pharm. cxii. 151), 100 pts. of a 19° dissolve 0·81 pt. of lophine, and at 21° from 0·84 to 0·91 pt. point, 2·70 to 2·75 pts.; and 100 pts. ether dissolve 0·26 pt. lophi 0·33 at 20°, and 0·32 at 21°. Of an indifferent substance, having n sition of lophine, and formed, together with the latter, by the decomp chlorate of hydrobenzamide at 160°–200° (p. 183), 100 pts. absolute 0·07 pt. at 16°, and 0·33 to 0·37 pt. at the boiling point; and 100 boiling point dissolve 0·69 to 0·74 pt. of the same substance.

Decompositions.—Lophine boiled with *nitric acid* forms nitrolop It is dissolved by *bromine*, without evolution of vapours of hydrobro the mass is dissolved in ether, and the solution mixed with alcohol spontaneous evaporation, beautiful yellow prisms with rectangular b these crystals give off bromine when heated, and, when water is p turn white and fall to powder (Laurent). Lophine in contact wit does not form any substitution-compound not even when the two together to 100° in a sealed tube for several weeks. A portion of th is decomposed into alcohol and hydriodic acid, which combines w (Gössmann and Atkinson.)

The lophine-salts are for the most part insoluble in water, and in alcohol.—They are rather unstable, having a tendency when recr up part of their acid and form basic compounds; this is particularly sulphate. (Gössmann and Atkinson.)

Hydriodate of Lophine, $C^{21}H^{16}N^2.HI$, is prepared like the hydrochlo lises readily in large needles, which are more soluble in alcohol an hydrochlorate. From a very acid solution, it separates in granular solves very easily in iodide of ethyl. In other respects it resembles t (Gössmann and Atkinson.)

Hydrochlorate of Lophine, $C^{21}H^{16}N^2.HCl$, separates quickly on coo tion of lophine in boiling alcohol containing hydrochloric acid. sufficient quantity of boiling alcohol be mixed with such a quantity no immediate precipitate is formed, the liquid on cooling yields well d

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he second modification of lophine, obtained by Kühn
lorate, also containing $C^{21}H^{16}N^2.HCl$, which crystallises in
at 160°. When hydrochloric acid is added to a hot satu-
lophine till the mixture exhibits a decided acid reaction,
on cooling in large transparent needles very much like the
If left for some time in the mother-liquor, they change
sms, an alteration which is probably due to loss of water.
ounds exhibit a similar change. When lophine is treated
acid, it becomes resinous, and can only be restored to the
ng the acid and crystallising from alcohol (Gössmann
drochlorate is nearly insoluble in water, but dissolves
Laurent). It has a slight acid reaction, dissolves more
hol than the pure base, and exhibits stronger fluorescence.
son.)
unites with *tetrachloride of platinum* when the solutions of
hol are mixed together, the double salt separating, as the
oloured crystals, the formula of which is probably
he chloroplatinate of Kühn's second modification of lophine
sation, the amount of which was found to be different in

$^{16}N^2.HNO^3$, forms fine light laminæ, devoid of lustre. When
give off 1 at. water (Laurent). From a concentrated
ne acidulated with nitric acid, the salt crystallises in small
ith strong nitric acid free from nitrous acid, are converted
mann and Atkinson.)
obtained in small shining rectangular laminæ, by heating
uric acid, and mixing the solution with hot water, where-
The alcoholic solution reddens litmus and is precipitated
r remaining in solution, so that, on adding ammonia, a pre-
btained. Laurent found in the dry salt 11·5 and 13·2 per
neutral salt requires 11·21 per cent. of sulphuric acid
tion of lophine to which excess of sulphuric acid has been
lowly, the sulphate separates in broad transparent tables,
effloresce on exposure to the air. When crystallised more
rates in large needles, which, if left for some time in the
small white opaque needles. At each crystallisation, the
d by frequent solution and recrystallisation, the acid may
. (Gössmann and Atkinson.)
lline compounds with *nitrate of silver* and *dichloride of*

th HORNBLENDE.

me applied by Breithaupt to a variety of felspar closely
t identical with it.
aginous or fatty bodies used for reducing the friction
e or carriage. (See *Ure's Dictionary of Arts, &c.* ii. 736;
Waggon Grease in *Richardson and Watts's Chemical Tech-*
and the article PARAFFIN OILS in this Dictionary.)
S. See *Ure's Dictionary of Arts, &c.* ii. 737; *Richardson*
ology, vol. i. pt. 4, p. 131; and the article PHOSPHORUS in

MESTONE, (p. 698).
LIMESTONE, (p. 697).
loride of silver (see SILVER).
Nitrate of silver fused at a low heat (see NITRATES).
non-nitrogenous substance obtained from lupine-seeds.
. xiii. 308.)
, granular, aromatic powder situated at the base of the cones
n 8 to 18 per cent. of the cones. It contains five different
il, a resin, a nitrogenous substance, a bitter principle, and a
nes contain about 2 per cent. of the volatile oil. This oil
e to beer its agreeable aromatic odour, while the bitter
it. (See HOP, p. 165.)
UM. The alchemical name of trisulphide of antimony.
which the joinings of vessels are closed are of different kinds

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according to the nature of the operations to be performed, and of th distilled in these vessels.

When vapours of watery liquors, and such as are not corrosive, it is sufficient to surround the joining of the receiver to the nose of the retort, with slips of paper or of linen covered with flour-paste. slips of wet bladder may be conveniently used.

When more penetrating and dissolving vapours are to be retaine employed of quicklime slacked in the air, and beaten into a liquid p eggs. This paste is to be spread upon linen slips, which are to b the joining of the vessels. This lute is very convenient, dries eas and sufficiently firm. Vessels may be formed of it hard enough to the wheel.

Lastly, when acid and corrosive vapours are to be retaine recourse to the lute called *fat lute*. This lute is made by forn some dried clay finely powdered, sifted through a silken sieve, an water, then beating this paste well in a mortar with boiled linse which has been rendered drying by litharge dissolved in it, and painters. This lute easily takes and retains the form given to i rolled into cylinders of a convenient size. These are to be applied, to the joinings of the vessels, which ought to be perfectly dry, beca ture would prevent the lute from adhering. When the joinings a this fat lute, the whole is to be covered with slips of linen spread wit whites of eggs. These slips are to be fastened with packthread. necessary to keep on the fat lute, because this latter remains soft, an solid enough to stick on alone.

Gutta percha may be united to glass, in tube apparatus, by fusin at the point of junction by means of a hot iron knife-blade.

Fine porcelain clay, mixed with a solution of borax, is well adapt the part received into an aperture being smeared with it.

LUTEOLIN. The yellow colouring matter of weld (*Reseda lut* isolated by Chevreul (J. Chim. méd. vi. 157), and has been mo and analysed by Moldenhauer (Ann. Ch. Pharm. c. 180) and by S and Paraf (*ibid.* Suppl. i. 139). Moldenhauer prepares it by exha alcohol, distilling off the alcohol from the extract; then washing wit the residue; exhausting it with ether; dissolving the residue left c ethereal solution in alcohol; adding a larger quantity of water boiling point; filtering hot; and leaving the filtrate to cool. Th purified by recrystallisation from boiling very dilute spirit containin alcohol. Schützenberger and Paraf exhaust the plant with alcoh extract with water, and heat the precipitate with water to 250° in s the luteolin then crystallises on the sides of the vessel on cooling, an by two crystallisations from superheated water.

Luteolin crystallises from solution in boiling dilute alcohol, also fr solution in dilute sulphuric or acetic acid, in yellow four-sided ne radiate groups; it may also be obtained in needles by careful sublin at 320° with partial decomposition, to a black-brown mass. It i slightly bitter, astringent taste; dissolves in 14,000 pts. of cold and 5 *water*, in 37 pts. *alcohol* [at what temperature?] and in 625 pts. of litmus paper slightly, and unites with *metallic oxides*. It dissolves colour in *caustic alkalis* and *alkaline carbonates*, remaining in the pu ammoniacal solution is evaporated (Moldenhauer). By prolon *ammonia*, it is completely dissolved, forming a deep yellow solu on evaporation a dark coloured residue which gives off ammonia w potash (Schützenberger and Paraf). In cold dilute *acids* it soluble; more easily in cold *concentrated sulphuric acid*, forming from which it is separated by water without alteration. It dissolves concentrated *hydrochloric acid*, more easily in warm concentrated nearly insoluble in that acid when cold. Dilute *nitric acid* acts u heated; strong nitric acid dissolves it with deep red colour, t decolorised by prolonged boiling, with formation of oxalic acid (Heated to 200° with *phosphoric anhydride*, it yields a red substanc with violet colour in ammonia (Schützenberger and Paraf). *chromate of potassium* and *sulphuric acid*, it yields formic acid. It d a solution of *gelatin*, but forms a green precipitate with a very dilute *chloride*, and colours a concentrated solution brown-red (Moldenha to Chevreul, the aqueous extract of weld forms beautiful yellow preci

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ate of lead, a blackish-grey precipitate with *ferrous sulphate*, *f copper*.

ler, luteolin contains 62·5 to 63·0 per cent. carbon and 3·70 deduces the formula $C^{20}H^{14}O^8$, requiring 62·8 C, 3·7 H, and hützenberger and Paraf, the air-dried substance heated to ent. water, and that which has been dried over sulphuric . at the same temperature. Luteolin dried at 150° gave by nt. carbon, and 3·5 to 3·8 hydrogen, whence Schützenberger ula $C^{12}H^8O^5$, which requires 62·1 C, 3·4 H, and 34·5 O. To lphuric acid, they assign the formula $C^{12}H^{10}O^6$, and to the $I^{10}O^6.H^2O$. A *lead-salt* precipitated from the alcoholic holic acetate of lead, gave by analysis 30·97 per cent. C, agreeing nearly with the formula $C^{12}H^8O^5.Pb^2O$, which 7·58 O, and 49·0 Pb^2O.

An organic base isomeric with benzylamine or toluidine derson (Ann. Ch. Pharm. lxxx. v.) in bone-oil. This oil ases soluble in hydrochloric acid; and on decomposing the sh and rectifying, lutidine passes over at about 145°. The l-tar naphtha and in shale naphtha, the liquid obtained shale of Dorsetshire (Gr. Williams, Chem. Soc. J. vii. 97); ses obtained by the distillation of peat. (Vohl, Jahresb Owen, Phil. Mag. [4] xx. 110; Jahresber. 1860, p. 359.) dentical with that from bone-oil, occurs among the products inchonine, and passes over in rectification between 160° and ho discovered this base (i. 869), and has recently instituted tween its properties and that of Anderson's base (Proc. ishes it as β-lutidine. The properties of the two bases re essentially different, as will be seen by the following com-

Bases.—Both bases when pure are colourless refractive ty of 0·9467 at 0°, and β-lutidine of 0·9555 at the same ils at 154°; β-lutidine betwen 163° and 168°. Vapour- periment (at 200°) = 3·839 (Anderson); of β-lutidine ms); by calculation = 3·699. It may be inferred from of β-lutidine has not been estimated above the truth, be- een taken too high, the vapour-density would have erred

cteristic smell, resembling that of its lower homologues, but aching the aromatic; this odour is never altered in the least on, and after boiling with nitric, chromic, or any other acid, alisation with an alkali. All the salts, however purified, addition of an alkali. *β-lutidine* has also a most character- of lutidine, and somewhat resembling that of nicotine, but ency of that base, and far more pleasant. No treatment nts, and no amount of purification of its salts, makes the ll, or causes it to approach, however distantly, to that of

when shaken with three or four times its bulk of water, it becomes milky, the base separating from it. *β-lutidine*, t less than 25 parts of water to dissolve it, and the solution warmed; on the contrary, a mixture of water and lutidine, becomes clear on warming. Hence it appears that lutidine le in hot than in cold water.

dine unite with *acids* and with *salts*, forming crystalline re very soluble.

with Cupric Sulphate. $(C^7H^9N)^2CuSO^4.4H^2O$.—When β- o a solution of cupric sulphate, a copious pale green pre- issolves in excess, forming a rich blue liquid, which after ed with brilliant blue prisms of considerable size, and the composition above given. They give off 2 at. water at s at 200°. (Williams.)

nCl^3.—Both bases give salts having this composition; but of *β-lutidine* with trichloride of gold became nearly solid, *lt* the precipitate occupied only half the bulk of the liquid, an a fourth of the quantity of water to dissolve it that was tidine. (Williams.)

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Mercuric salt of Lutidine, $C^7H^9N.HgCl^2$. This salt separates fro alcoholic solutions of lutidine and mercuric chloride, as a white from dilute solutions it is gradually deposited in radiating crystal boiling water, with partial decomposition; more freely, and wit boiling alcohol. (Anderson.)

Palladium-salts.—The chloropalladite of β-lutidine, $2(C^7H^9N$ tained, as a nearly solid mass of garnet-red prisms, on leaving a m hydrochloric acid, and chloride of palladium, to itself for four days. a long time to 100°, it is decomposed, 1 at. hydrochloric acid being of the salt, and leaving the compound:

$$C^{28}H^{28}N^4Cl^6Pd^2 = 2(C^7H^9N.HCl).PdCl^2.2C^7H^9N.Pd$$

The *chloride of palladio-β-lutidyl-ammonium*, $N^2\left\{\begin{matrix}2(C^7H^9)'' \\ Pd''\end{matrix}\right\}Cl^2$, t the last-mentioned substance, is easily obtained by acting on chlori solution with β-lutidine. This base is not easily soluble, and pu (Williams.)

On mixing solutions of hydrochlorate of *lutidine* and chloride of similar in concentration to those above employed, no crystals we time that the contents of the vessel containing the β-lutidine ha and even after a month's repose, the quantity obtained was much β-lutidine.

Platinic salts.—The *chloroplatinates* of both bases hav $2(C^7H^9N.HCl).PtCl^4$, and crystallise in rectangular tablets; but exhibits the same superior facility of crystallising that is observed i gold- and palladium-salts. The presence of hydrochloric acid in exc the formation of the lutidine-salt (Anderson); but Williams finds case with the β-lutidine-salt, a mixture of the hydrochlorate of β-lut chloride and a large excess of hydrochloric acid instantly becoming

Decomposition of the Platinic salts by boiling.—Chloroplatinate o to decompose the instant the solution enters into ebullition, an insol beginning to deposit, and rapidly increasing in quantity. After

this salt has the composition of *tetrahydrochlorate of platino-lutidine*, β

The solution of chloroplatinate of lutidine, on the other hand, active boiling before any deposit began to form; and even after sev the deposit was very small.

Platinous salts.—When equal weights (1 grm. each) of platin β-lutidine were mixed in an apparatus surrounded with a non-condu temperature rose from 16° to 84°, and a hard brittle product was almost exactly in composition with the formula $2C^7H^9N.PtCl^2$. treated with platinous chloride under exactly the same condition rose two degrees higher; but the product, instead of becoming a remained of the consistence of treacle.

Substitution-derivatives of Lutidine.

Ethyl-β-lutidine.—A mixture of 1 vol. β-lutidine and 2 vol. iodid a sealed tube to 94° for three minutes, solidified on cooling to a mass *of ethyl-β-lutidine*, $C^7H^8(C^2H^5)N.HI$.—The *platinum-salt* prepared usual way, crystallises in superb orange-coloured fronds, containin $PtCl^4$. This salt when boiled with water turns black, and deposits two days' boiling, it yielded 27·5 per cent. of the metal, the original sa per cent. (Gr. Williams.)

Ethyl-lutidine.—A mixture of lutidine and iodide of ethyl in the heated to the same temperature for the same time, showed no signs on cooling. It required an hour's digestion to effect combination; hours, only half the product had crystallised, the rest remaining in t (Gr. Williams, Proc. Roy. Soc. xii. 311.)

Methyl-β-lutidine, $C^8H^{11}N = C^7H^8(CH^3)N$.—β-lutidine mixe methyl, becomes heated, and forms *hydriodate of methyl-β-lutidine*, in water and alcohol, but nearly insoluble in ether. Its alcoholic s to a syrup, remains liquid if left at rest; but on touching it, bea shoot through the liquid, which soon becomes completely solid. T $2(C^8H^{11}N.HCl).PtCl^4$, forms crystals containing 30·29 per cent. plat liams, Ed. Phil. Trans. xxi. [2] 317.)

Lycine. (Husemann and Marmé, Ann. Ch. Pharm. Suppl

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horn (*Lycium barbarum*). The leaves are repeatedly boiled
yield but a small product); the extracts are precipitated with
and the filtrate, freed from lead by sulphydric acid, and
ate of sodium, is evaporated to a third of its original volume.
y acidulated with sulphuric acid, is then precipitated with a
ybdate of sodium, or a mixture of 30 at. tungstate and 1 at.
e light yellow precipitate, after washing with water acidulated
xed, while still moist, with carbonate of barium, dried over the
ed with boiling alcohol. The extracts leave, after evapora-
rupy residue, from which the base may be dissolved out by
l, while a resinous body remains undissolved. The hydro-
a strong acid reaction, is easily soluble in water, sparingly in
insoluble in ether, and crystallises from alcohol in dazzling
ometimes half an inch long, and from water in fern-like groups
base, obtained by treating the hydrochlorate with carbonate
is a white, radio-crystalline, deliquescent mass, which has a
aste, dissolves easily in water and alcohol, very sparingly in
ecomposition when heated. Most of its salts are crystallisable,
ter; some of them are also deliquescent.

The fine dust of lycopodium, or clubmoss, consists of the
en diffused or strewed in the air, it takes fire from a candle,
h of lightning. It is used in theatres.
hese spores, Bucholz extracted 60 parts of a fixed oil soluble
15 of mucilage, 895 of a substance insoluble in water, alcohol,
tine, and cold alkaline leys.
5·0 per cent. chlorophyll, 25·0 extractive matter and acetate of
salts of calcium, magnesium, manganese, iron, lead (?), and
ulose.
odium is used as a mordant, on account of the large quantity
which it contains. (Pelouze et Frémy, *Traité*, vi. 469.)

E, *Touchstone*, or *Basanite*, a velvet-black siliceous stone or
count of its hardness and black colour, for trying the purity of
ee GOLD (ii. 929).

id, which fills the lymphatic vessels, is colourless or yellowish
lood-corpuscles happen to be mixed with it. It is sometimes
lightly turbid or opalescent, of a faintly saline taste and mawk-
reaction is usually alkaline. It coagulates in from four to
discharge from the lymphatics, then forming a gelatinous,
gulum, which gradually contracts more firmly, and encloses a
alled lymph-corpuscles: this coagulum usually occupies but a
portion to the serum.
gical elements of lymph, in addition to fat-globules and nucleus-
rue lymph-corpuscles, which, however, do not differ essentially
rpuscles. In lymph that has been carefully collected, blood-
d, excepting when the liquid has been obtained from the
, or from animals that have been starved to death. (H. Nasse,
. 363–410.)
nts of lymph are in general similar to those of blood, without
e spontaneously coagulating substance of the lymph is perfectly
n of blood. In human lymph (obtained in cases of disease or
Colberg found 0·52 per cent. and L'Héritier 0·32 per cent. fibrin;
ne horse, from 0·04 to 0·33 per cent. has been found by different
und that frogs which had been starved to death during winter
y free from fibrin; whereas Nasse found that the lymph of frogs
a heated room still coagulated.
e lymph has the same general properties as blood-albumin.
ger found, however, that albumin from the lymph of a horse,
reaction with vegetable colours, did not coagulate on boiling,
n, a membrane was formed on the surface of the liquid as
buminate of sodium had been present. This lymph-serum was
acetic acid, unless boiled after acidification: neither was it
hence the absence of casein may be inferred; nor by ether.
bumin has been found to vary from 0·434 to 6·002 per cent.,
from 1·2 to 2·75 per cent. In the ash of lymph-albumin, even
n with water and spirit, Nasse found an extraordinarily large
bonates.

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Fat occurs in lymph only in small quantities, and for the most part form; in the lymph of the horse, Nasse found 0·0088 per cent. of free f per cent. of alkaline salts of fatty acids; while in human lymph, Ma berg found 0·264 per cent. of a pale reddish fat.

The lymph also contains lactates.

In horses' lymph, Nasse found 0·0755 per cent. of extractive in alcohol, and 0·9877 per cent. soluble in water only; while, accor and Schlossberger, the whole of the extractive matters amount to Nasse was unable to detect urea in the lymph of the horse.

Mineral constituents.—In lymph, as in all the animal fluids, chlorid the preponderating mineral constituent: in horses' lymph, it amounts, acc to 0·4123 per cent. Alkaline carbonates were found by Nasse in the quantity being estimated at 0·056 per cent.; but Geiger failed in dete the ash of the solid constituents of the lymph, however, the latter found of alkaline carbonates. The presence of ammoniacal salts, which by Nasse, has been definitely established in horses' lymph by Geiger and Nasse found that horses' lymph is comparatively rich in sulphuric aci in it pre-formed; he estimates the quantity of sulphate of potassiu cent. Alkaline phosphates occur only in very small quantities. salts, with a small quantity of ferric oxide (arising probably from th few blood-corpuscles), were found by Nasse to amount to only 0·031 per lymph.

The quantity of water in lymph appears to be very variable, but n in the blood-plasma. In human lymph, Marchand found 96·926 per cent. found 92·436 per cent. water; in the lymph of horses, the quantity ha vary from 92·5 to 98·37 per cent.

Nasse has instituted an interesting comparison (based on direct an the composition of the lymph and of the blood-serum of the horse, from w that the individual salts stand to one another in precisely the same liquids, although their absolute quantity is very different, on account o tively larger proportion of water in the lymph.

There are also considerable differences in the proportions in which t stituents stand to the organic matters in the two liquids: while 10 correspond to 1036 pts. of organic matters in the blood-serum, the rati is as 100 to only 785. According to Marchand and Colberg, human organic and inorganic matters in nearly equal parts. (*Lehmann's Physiolo* translated by Day, ii. 299.)

LYNCURION. A Greek name for Amber.

M.

MACE is the *arillus* or envelope of the fruit of the nutmeg (*Myris* It forms a somewhat thick, tough, unctuous, reticulated membrane, o brown or orange colour; has a somewhat more agreeable odour than warm and pungent taste, and is used as a condiment in cooking.

Mace contains two oils, one of which is unctuous, bland, and of the butter; the other, which is obtained by distillation with water, is thinn By cohobating four times, 4·7 per cent. oil may be obtained (Hoff Pharm. xliii. 296); from old mace, 4·1 per cent. (Bley, *ibid.* xlviii. 94) parent and colourless; of specific gravity 0·931; smells strongly of m burning aromatic taste. It forms a permanent liniment with aqueous a

MACLE is the name given to certain spots in minerals of a deepe rest; sometimes proceeding from difference of aggregation, sometimes fr of a foreign substance: clay-slate, for example, may be macled with iro

MACLES. Twin-crystals (ii. 159).

MACLURIN. Syn. with Morintannic Acid (p. 1049).

MADDER. *Garance. Krapp.*—The root of *Rubia tinctorum*, e in dyeing for the production of a variety of colours, namely, red, pink, and chocolate. Other species of *Rubia* yield similar colouring matters, an as dyeing materials; viz. *R. Mungista*, or *Munjeet*, which grows in th regions of Hindoostan, and is used in that country for producing the red figures seen in the chintz calicoes of the East Indies; and *R. peregrina*, vated in the Levant, where it is called *Alizari*, and imported into this the name of *Turkey-roots*; but *Rubia tinctorum*, or *dyers' madder*, is t

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thrives best in a warm climate, and is grown extensively also in Alsace and in Naples; in the north of Europe it ion.

ıave a peculiar smell, and a taste between bitter and sweet. ıely, being sometimes yellow, sometimes orange-red, reddish- e more or less hygroscopic; so that even when closely packed wder, they slowly attract moisture, increase in weight, and at lent condition, forming a firm coherent mass. Some kinds e of Alsace and Holland, when mixed with water and left to ive a thick coagulum or jelly—an effect which does not take ith Avignon madder. The madder of Avignon contains so much effervesce with acids. The herbaceous parts of the plant, attle, are found to communicate a red colour to their bones. es which madder presents, as a dye-stuff, are the following:— ing, according to the mordants and the method of treatment, t colours and shades; such as black; red of different kinds, o a bright red and delicate pink, besides the peculiar colour o purple of various shades, from a dull reddish-purple to a lilac, as well as chocolate of all shades.—2. Its colouring inity for cotton fibre, and a great affinity for mordants; so secure a good white on the parts of the tissue to which no .—3. The compounds which its colouring matter or matters ss an unusually stable character; so that they may be ex- ment to the colour, to the action of various agents for the odifying the shade.

ion of Madder. There is probably no subject connected ich has given rise to so much discussion as the composition al nature of the colouring matters to which it owes its valu- ect has engaged the attention of a great number of chemists, cially mentioned, Robiquet and Colin, Kuhlmann, Gaulthier unge, Schunck, Schiel, Higgin, Debus, Strecker, Rochleder, Nevertheless, our knowledge of madder, as compared with other colouring principles, is still confused and uncertain. sts (Sacc, for example) and many manufacturers, madder principle, while most others admit the existence of at least urin. Moreover, according to some chemists, the colouring ready formed; whereas others suppose that fresh madder generating substance, which subsequently, by a kind of fer- e colouring matter properly so called: the latter, which is be based on the most trustworthy experiments.

cial madder is exhausted with boiling water, a dark-brown l, having a taste between bitter and sweet. On adding d to this liquid, a dark-brown precipitate is produced; while ecomes clear, and appears of a bright yellow colour. The zarin, purpurin, rubiacin, two resinous colouring matters, active matter, and a peculiar nitrogenous substance. The recipitate contains the bitter principle and the extractive as sugar, and salts of potassium, calcium, and magnesium. can be detected in the watery extract. After the madder sted with boiling water, it appears of a dull-red colour. It colouring matter, which cannot, however, be extracted with lis, since it exists in a state of combination with lime and ounds which are insoluble in those liquids. If, however, ith boiling dilute hydrochloric acid, that acid dissolves a , alumina, and sesquioxide of iron, as well as some phos- ium, which may be discovered in the filtered liquid; and ing well washed, be treated with caustic alkali, a dark-red ives with acids a dark reddish-brown precipitate of alizarin, nd pectic acid. The portion of the madder left after treat- ids, and alkalis, consists almost entirely of woody fibre.

hown to exist in ordinary madder, the most important are l purpurin, which are in fact the essential red colouring They were discovered by Robiquet and Colin, to whom rst memoir of any importance relating to the chemistry of [2] xxxiv. 225.)

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Alizarin, the *Lizaric acid* of Debus, *Madder-red* of Runge, *rouge* of Gaulthier de Claubry and Persoz, was obtained by Robiqu sublimate, in beautiful reddish-yellow needles; but the mode of prep adopted left it uncertain whether the alizarin pre-existed in madde of decomposition of some other body produced by heat.

It may, however, be extracted from ordinary madder, as used b action of solvents, and obtained in crystals without sublimation: I in ordinary madder may be inferred (see i. 114; and for detai *Gmelin's Handbook*, xiii. 326, and xiv. 130). Its composition cann definitely established. Wolff and Strecker's formula, $C^{16}H^6O^3$, is n with the relation of alizarin to chloronaphthalic acid, $C^{10}H^5ClO^3$, b pounds being converted, by the action of nitric acid, into phthalic a formula, $C^6H^4O^4$, appears to explain more clearly the formation of al (p. 745): it must be remembered, however, that the formula of rub means well established. Alizarin is very little soluble in water, more but nearly insoluble in aluminium-salts. Its alkaline solutions hav or purple colour, and it forms lakes of various colours with the metallic oxides.

Purpurin, the *Madder-purple* of Runge, *Matière colorante ros* Claubry and Persoz, *Oxilizaric acid* of Debus, is extracted from m processes as alizarin, and separated from it by its superior solubili It bears considerable resemblance to alizarin, yielding a crystallin heated, and being very sparingly soluble in water, but more s The properties by which it is distinguished from alizarin, are its boiling alum-liquor, forming a solution of a beautiful pink co fluorescence; and secondly, the colour of its alkaline solutions, which bright red; whereas alizarin forms violet solutions with alkalis. might, however, be produced by the admixture of some foreign substa and accordingly some chemists, as already observed, do not rega distinct substance, but attribute all the colouring power of madder to are, however, other characters which show beyond doubt that purpu substance: viz.—1. Its decomposition when exposed to the air in alk colour of the liquid then changing from bright red to reddish-yellow, a appearing almost entirely, after which purpurin can no longer be disco tion, whereas alizarin suffers no such decomposition (Schunck' properties. Stokes has shown that when a solution of purpurin is exa the spectrum which it exhibits is totally different from that which is manner by alizarin. (See LIGHT, p. 638; also PURPURIN.)

Considerable difference of opinion likewise exists as to the relative and purpurin as dyeing materials. According to Robiquet and Schun most permanent madder-colours are produced by alizarin; whereas Ru are of opinion that the liveliest tints are produced by purpurin, and t likewise plays the principal part in the manufacture of Turkey-red. Kopp, on the other hand, the real basis of Turkey-red is alizarin; and that purpurin, though it dyes mordanted fabrics perfectly, does not so great a degree of stability, and has not so great an affinity for oiled

From Schunck's experiments, it appears that all the usual madde obtained by means of alizarin, and that the colours so produced are as as ordinary madder-colours are after a long course of treatment wit They are likewise equally fast, and quite equal to ordinary madder power of resisting decomposition by soap, alkalis, &c.

In short, the final result of dyeing with madder and its preparatio simply the combination of alizarin with the various mordants employe be shown, indeed, that the finer madder-colours contain little besides a nation with the mordant. If, for instance, a few yards of 'madder-pink c with hydrochloric acid to remove the alumina of the mordant, then treated with caustic alkali, a violet solution is obtained from which yellow flocks consisting of almost pure alizarin. Purpurin, on the oth to have almost entirely disappeared from all madder-colours which jected to a long course of after-treatment; a result quite in accordance w mentioned of the decomposition of purpurin in alkaline solution on ex (Schunck.)

Madder likewise contains certain yellow colouring matters: but th not positively injurious, in the process of dyeing. **Rubiacin** is a ye colouring matter, coinciding in most of its properties with the *madder-* It is only slightly soluble in boiling water, but dissolves more freely in

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, on cooling, in greenish yellow lustrous scales and needles. It osition in strong sulphuric and in boiling nitric acid, and with Its compounds with metallic oxides are mostly red. When ution of ferric chloride or nitrate, it dissolves entirely, yielding which gives with hydrochloric acid a flocculent precipitate of

olouring matters already mentioned (p. 742), one is a dark- body, very soluble in alcohol, and melting at a little above ish-brown powder, less soluble in alcohol than the preceding. ters, together with rubiacin, constitute probably the tawny tter of madder mentioned by the older chemists. They do nsity of the colours dyed with madder, and exert a very pre- ity of the dyes. If printed calico be dyed with a mixture of ese three colouring matters, the colours are found to be both ul than when alizarin is used alone. The red acquires an rple a reddish hue, whilst the black is less intense, and the n white have acquired a yellowish colour. The effect of these herefore, be counteracted as much as possible by preventing g in the dye-bath, or from attaching themselves to the fabric. tituents of madder are also for the most part injurious in dye- state in which it exists in the root, is probably an indifferent uence of the ease and rapidity with which it passes into pectic judicially in dyeing, by combining with the mordants and ing up the colouring matter.

ter of madder, when in an unaltered state, produces no inju- ut by the action of oxygen, especially at elevated tempera- colour, and then contributes, together with the rubiacin and s, to deteriorate the colours, and sully the white parts of the m dirty reddish-brown tint which a piece of calico exhibits, nprinted portions, after having been dyed with madder: the ne of the objects of the after-treatment with soap and other s of manufacturing garancin, this substance is partly decom- the subsequent washing: and this explains, in a great mea- nd brilliancy of garancin colours, as compared with madder natter, when pure, has the appearance of a yellow syrup, like water and in alcohol, and is not precipitated from its aqueous metallic salt; but the solution, if evaporated in contact with rown, and then gives an abundant brown precipitate with ous solution mixed with hydrochloric or sulphuric acid, and l deposits a dark-green powder. Hence this extractive matter genin by Schunck, rubichloric acid by Rochleder. The and the madder-yellow of Runge appear to be mix- atter with a bitter principle.

in madder is probably glucose: it has not hitherto been sed state; but it yields alcohol and carbonic acid by fer- sugar. The woody fibre which remains after madder has d by the action of various solvents (p. 742), always retains a h tinge, from the presence of some colouring matter which oved, and seems to adhere to it in the same way as it does to cotton.

ituents of madder-root have been analysed by H. Köchlin 4) and K. Moy (*ibid.* liv. 346); those of the seed by Schiel).

	Ash of root.			
	From Alsace.		From Zealand.	
	a.	*b.*		Ash of Seed
. . . .	29·35	26·64	3·42	20·08
. . . .	15·89	11·67	25·76	6·20
. . . .	34·54	29·25	16·29	29·89
. . . .	3·72	3·68	3·17	2·48
. . . .	1·18	3·36	2·67	3·74
e . . .	5·26	4·62	16·84	5·10
. . .	3·68	2·14	2·86	3·00
. . .	1·64	5·36	16·41	19·22
. . . .	4·71	13·25	12·58	10·29
	99·97	99·97	100·00	100·00

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The Alsace madder (*a*) grown on a highly calcareous soil yielded 8· *b* yielded 8·4 per cent. The seed of Avignon madder gave 8·14 per c

Formation of the Red Colouring Matters.—The extraction of alizar from madder by the action of solvents shows that these colouring ma formed in madder in its ordinary state, as used by the dyer. But i question whether they exist in the root while growing or when n whether they are formed by any subsequent process of chemical chan long been known that when ground madder is kept tightly packed stantly improves in quality for several years, after which it again det was always supposed that this effect was due to some process of s The real nature of the change, however, remained for a long time unk supposes that the change which goes on consists in the conversion of purin; but this would constitute anything but an improvement in q colours produced by purpurin are in most respects inferior to those of a this, alizarin is a body not easily decomposed, unless exposed to th potent agents; and any portion of it once formed in the root, would p action of air and moisture for a very long period of time, if not entir of Manchester states, as the results of his experiments on this subject, in madder a peculiar albuminous ferment, which, by acting on the xa to the formation of colouring matter; and that this process takes plac even during the short period of time occupied in dyeing. This vie firmed in its main features by the experiments of Schunck.

That the whole of the colouring matter of madder does not exist rea article as used by the dyer, may be rendered evident by a simple madder be exhausted with cold water, the clear watery extract does alizarin or other colouring matter, since these are almost insolubl Nevertheless, the extract when gradually heated is found capable of dy way as madder itself. If made tolerably strong, it possesses a deep y a very bitter taste; but if it be allowed to stand in a warm place fo gelatinises, and the insoluble jelly which is formed is found to possess tinctorial power of the liquid, while the latter has lost its yellow c taste. Hence it may be inferred that the substance which imparts t bitter taste and yellow colour, is capable of giving rise to the forma portion of colouring matter. By extracting madder with boiling wate gelatinisation or coagulation is prevented, and the extract retains its y bitter taste; a proof that the coagulation observed in the extract with result of some process of chemical change which is arrested when th sufficiently raised. When the extract is agitated with a little animal ch absorbs the bitter principle, and gives it up again to boiling spirits o evaporation leaves it in an almost perfect state of purity. In this obtained a substance to which he has given the name of Rubian, principal characteristics are these:—It is amorphous and shining like yellow colour and an intensely bitter taste, is easily soluble in water is not a colouring matter in the practical sense of the word, for it g in dyeing only the faintest shades of colour. But if its watery solutio sulphuric acid and boiled, it gradually deposits a quantity of insolu and becomes almost colourless. These flocks, after being well washe dye exactly the same colours as alizarin. In fact they contain aliza gives the reactions of sugar. Taking this fact into consideration, it to give an account of the principal change which takes place in the p facturing garancin. It is evident that during this process, the easil becomes converted into the difficultly soluble alizarin, that there is in an actual formation of colouring matter which is added to that already root. A similar change takes place when caustic alkali is used in pl A solution of rubian on being mixed with caustic potash or soda, simp on being boiled, it becomes dark purple and deposits a purple powde chiefly of a compound of alizarin with alkali, insoluble in caustic lye. also decomposes rubian with great facility; but in order to effect its is not indifferent what ferment is taken; a peculiar ferment is essentia A solution of rubian may be left for several days in contact with ye albumin, casein, emulsin, &c., without showing any sign of change. of madder with cold water be mixed with a large excess of alcohol, flo colour are precipitated, which, after being well washed with alcohol, a sist chiefly of an azotised principle called Erythrozym, which exert powerful decomposing effect on rubian. If some of this substance a watery solution of rubian, and the mixture be left to stand at th perature, the rubian is found after a few hours to be as completely

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strong acid or caustic alkali, though no evolution of gas
f fermentation have been manifested. The solution, if
st as an extract of madder with cold water does, under the
ly, when mixed with cold water, is found to be almost in-
nly a slight colour, but contains sugar in solution, while the
arin mixed with the ferment. This process of decompo-
of the fact, well known to madder dyers, that if the
ly to the boiling point, instead of gradually, as is the
cts ensue. In fact, the sudden heating puts a stop to
would be the case in any other process of fermentation,
llows it to exert its full decomposing power on the rubian.
mixing together several sorts of madder, one containing
n proportion to ferment, the other a superabundance of
t. The improvement which takes place in the quality
is probably also an effect of the same cause. Indeed,
t the alizarin, which undoubtedly exists ready formed
formation to the action of fermentation on rubian;
fresh madder roots goes far to prove that this is in fact
oot contains no trace of ready formed colouring matter.
en taken out of the ground and cut small, without being
colours when used for dyeing in the common manner.
fter being cut into pieces as quickly as possible, with
ract was obtained, which contained rubian, but which,
been driven away, was found incapable of imparting to
t shades of colour; while the portion of the root left un-
eing subjected to the same test as the extract, imparted
han the latter. It was evident, therefore, that the alcohol
aration between the colour-producing body and the agent
mstances, is destined to effect its transformation into
e relation, it is apparent, subsists between rubian and
dalin and emulsin.

osition from all other known ferments, containing but a
ot exceeding 4 per cent. It acts on an aqueous solution
nanner as yeast, giving rise to the formation of alcohol,
uccinic acid, but it is distinguished from all other fer-
on rubian.

o the action of acids, alkalis, or erythrozym yields alizarin
on might at first sight be supposed to consist simply in
nto these compounds, according to the usual mode of de-
ne real decomposition is however much more complex, the
alizarin and glucose only. The part insoluble in cold
esides alizarin, two resinous colouring matters, namely,
soluble in alcohol, and Verantin, $C^{14}H^{10}O^5$, less soluble
tion to these, there is uniformly found accompanying the
ing, as far as general appearance and properties are con-
ubstances as rubiacin. The third body is, however, in
hen acids have been employed for the decomposition of
s found to have the following properties:—It is tolerably
ystallises in lemon-yellow silky needles; it is decomposed
ne action of nitric and concentrated sulphuric acids; this
ins, according to Schunck, $C^{22}H^{24}O^{10}$. When alkalis are
ianin is replaced by Rubiadin, $C^{16}H^{14}O^5$,* which is a
l golden-yellow scales, insoluble in water, but soluble in
tilised when heated. But when rubian is decomposed
either of these two, but in their place Rubiafin, a
osition with rubiadin, and resembling it in most of its
stinguished from it by passing into rubiacic acid when
This substance is usually accompanied by another of
biagin, of which it is difficult to say whether it must be
the others, since it has not been obtained in a state of
lies which accompany alizarin make their appearance so
tances above mentioned, that their occurrence cannot be

formula $C^{28}H^{34}O^{15}$, Schunck's view of the formation of
esented in equations as follows:—

formula, $C^{32}H^{13}O^9$; but this is improbable on account of the uneven
toms ($O = 8$).

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a. Formation of alizarin ($C^{14}H^{10}O^4$ according to Schunck):

$$C^{28}H^{34}O^{15} = 2C^{14}H^{10}O^4 + 7H^2O.$$

b. Of verantin and rubiretin:

$$C^{28}H^{34}O^{15} = C^{14}H^{10}O^5 + C^{14}H^{12}O^4 + 6H^2O.$$

c. Of rubianin and glucose:

$$C^{28}H^{34}O^{15} + H^2O = C^{22}H^{24}O^{10} + C^6H^{12}O^6.$$

d. Of rubiadin and rubiafin:

$$C^{28}H^{34}O^{15} + 2H^2O = C^{16}H^{14}O^5 + 2C^6H^{12}O^6.$$

Or rubiadin and rubiafin may be considered as products of the further metamor of rubianin:—

$$C^{22}H^{24}O^{10} + H^2O = C^{16}H^{14}O^5 + C^6H^{12}O^6.$$

It appears, then, that rubian undergoes, not one, but three different proces decomposition when acted on by acids, alkalis, or ferments; that the formation of is connected not with that of alizarin, but with that of rubianin and its allies, an in fact there is no reason why only one of these processes should not take place exclusion of the others; why, for instance, rubian should not be so decomposed yield alizarin alone, without any of the accompanying bodies, which are from this of view, not only a source of loss, but also prejudicial in practice.

The formation of alizarin and of the other products of rubian above mentioned not depend upon oxidation. Nevertheless, according to Schunck, rubian does a partial oxidation when its aqueous solution, mixed with an alkali or alkaline is exposed to the air, the product formed being rubianic acid, $C^{52}H^{30}O^{27}$, (or p $C^{52}H^{30}O^{28} = C^{52}H^{30}O^{14}$). Its formation may perhaps be represented by the equ

$$\underset{\text{Rubian.}}{C^{28}H^{34}O^{15}} + O^5 = \underset{\text{Rubianic acid.}}{C^{26}H^{30}O^{14}} + 2CO^2 + 2H^2O.$$

It is a true glucoside, and is resolved by the same agents which effect the deco tion of rubian into alizarin and glucose, no secondary products making their a ance; perhaps thus:

$$\underset{\text{Rubianic acid.}}{C^{26}H^{30}O^{14}} + 2H^2O = \underset{\text{Alizarin.}}{C^{14}H^{10}O^4} + 2\underset{\text{Glucose.}}{C^6H^{12}O^6}.$$

For further details respecting all these products, see RUBIAN.

Use of Madder in Dyeing. The chief use of madder is in cotton-dyei calico-printing. In woollen-dyeing it is not so much employed, especially i country, only the ordinary woollen goods being dyed red with it; the colour is bright as that obtained with cochineal or lac, although more permanent and c Silk is seldom dyed with madder, because cochineal affords brighter tints.

The series of operations usually adopted for printed calicoes is as follows:—

1. The calico having been singed and bleached, the mordant is printed on; n '*red liquor*' (acetate of aluminium containing a small quantity of sulphate) for pink; '*iron liquor*' (ferrous acetate) for violet, purple, or black; and a mixture with *red-liquor* for chocolate.

2. The printed cloth is hung up with free access of air for about two days. this process of "ageing," the mordant undergoes important changes, and becom great extent insoluble, and therefore fixed in the cotton: *red-liquor* parts with part of its acetic acid, and its alumina remains as a highly basic sulphate; *iron* absorbs oxygen and loses acetic acid, and is thus converted into a basic ferric Of late years, a "rapid ageing process" has come into extensive use; it con passing the printed calico through a heated chamber, the atmosphere of which exactly saturated with water-vapour. This process is frequently completed in half an hour, but the time required for it, as well as for the ordinary ageing varies with the amount of mordant upon the cloth.

3. The next operation is called "dunging," and consists in passing the cloth t a hot mixture of cow-dung and water. During this process, superfluous por the mordant, which would otherwise get detached from the cloth during the dye would be precipitated in combination with colouring matter upon the unprinted are removed (perhaps in combination with organic constituents of the bath), remainder is converted more or less completely into phosphate. For a good years past, the use of cow-dung in this process has been to a great extent sup by that of an artificial preparation known as "dung substitute," first introdu Mercer, the essential constituents of which are alkaline phosphates and arsenates DYEING, ii. 353.)

4. Steeping in the madder-bath, which is kept lukewarm at first, and gr raised to the boiling heat.

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he fabric through a boiling mixture of bran and water, or
weak solution of chloride of lime, or by "crofting," that
on the grass to the action of air and light, or by several of

of colours, other dye-stuffs are sometimes added to the
or fustic for orange, logwood for blacks, &c.
to the operations of madder-dyeing, see *Ure's Dictionary*
and TURKEY-RED.
h take place during the process, may be shortly described
the water of the dye-bath extracts the more soluble con-
as the sugar, extractive madder, and bitter principle
nposed by the ferment, and the colouring matter thereby
dy existing in the root. As the temperature rises, the
h as the alizarin, purpurin, rubiacin, resinous colouring
d, begin to dissolve, and at the same time combine partly
ric, partly with the lime and other bases contained in the
, and thus permit the liquid to take up fresh quantities
ctive matter acquires at the same time a brown colour by
and oxygen, and covers the white portions of a piece of
brown tinge. At the same time the alumina mordant
h-red colour, and the iron mordant a black or brownish-
er removal from the dye-bath, presents a very unsightly
tes, and at the same time brighten the colours by removing
rs, extractive matter, &c., and leave nothing but the
nordants, is the object of the fifth operation or series of
But even this treatment, though sufficient for the more
ls, does not completely remove the foreign substances;
scriptions of printed calicoes are subjected to an after-
ws: "The goods, after being very fully dyed, generally
then washed, are passed for some time through a solu-
to a moderate temperature. By this means, a great deal
be seen by the red tinge of the soap-liquor, and the purity
st entirely restored. During this process, the brown and
probably removed by double decomposition, the alkali of
dissolving them, while the fat acid takes their place in
ed, the goods are passed through a weak solution of acid,
an acid tin-salt, which causes the colours to assume an
which the action of the acid liquid is to be arrested, can
ice. The next step in the process is, after washing the
with soap-liquor in a close vessel under pressure. By
ass for some time after the first soaping, the use of acid
ocess then becomes much more tedious. In this way are
ks and lilacs, which, for delicacy of hue, combined with
passed by any dyed colours known in the arts. Whether
yed forms an essential constituent of these colours, is not
obable that it contributes to their beauty and durability.
ey always contain fat acid. If a piece of calico which
es just described be treated with muriatic acid, the colour
ain is left in its place. This yellow stain disappears on
ing with water, with alkali, yielding a solution of a beau-
ution gives again, with an excess of acid, a yellow floccu-
filtration, dissolves almost entirely in boiling alcohol, and
affords needle-shaped crystals of pure alizarin, mixed with
he latter, therefore, seems to occupy the place taken up by
nt with soap." (Schunck.)
or the production of permanent madder-colours is the
ity of lime in the bath. This was first pointed out by
g produced very fine reds at Rouen, where the water is
reatest obstacles in dyeing the same reds at Logelbach
r is nearly pure; but on adding chalk to his dye-bath, he
d as permanent as those which he had formerly produced
been known that Avignon madder, which is grown on a
ntains so much calcic carbonate as to effervesce with acids,
colours, whereas Alsace madder requires the addition of
e same effect. The lime appears to act by uniting with
lder (the rubiacin, pectic acid, &c.), which when taken up
uantity, act injuriously on the colour: for Schunck and

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Robiquet have shown by experiment that, in dyeing with pure addition of lime is rather injurious than otherwise, as it weakens adding to their durability. On the other hand, the addition of rubi colouring matters, or of pectic acid to alizarin was found to be very then acquiring an orange, and the purple a reddish hue, while brownish, and the white parts of the fabric assumed a yellowis effects disappeared completely as soon as the foreign colouring ma saturated with lime, the tinctorial power of the alizarin then reap original intensity. Too great a quantity of lime must however be take hold of the alizarin itself, and prevent it from uniting with th

Preparations of Madder. Since madder contains a variety impair the brightness and permanency of the colours produced by rin, it follows that the process of dyeing with it must be greatl previous removal of these substances. This object is attained by t sulphuric acid, which destroys the rubiacin, resinous colouring matte tractive matter, &c., and at the same time, by its action on the rub the madder, increases the quantity of alizarin and purpurin. M produces dyes which require less clearing than ordinary madder is this further advantage in its use, that nearly all the colouring ma is available for dyeing, whereas when crude madder is employed, n colouring matter remains in the residue unutilised. These conside the use of the following preparations of madder:

1. **Sulphuric Charcoal** (*Charbon sulphurique*).—This na Robiquet to a product which he obtained by treating pulverised siderable quantity of rather strong sulphuric acid for several hours water, filtering, washing, and drying the residue. It dyes strongl fine colours; but being difficult and costly to prepare on the large sc has been abandoned, excepting for the preparation of coloring, a into commerce by MM. Lagier and Thomas, and obtained by exh ric charcoal with alcohol and distilling the solution to the consiste

2. **Garancin**, first prepared by Lagier, Robiquet, and Coli similar manner to sulphuric charcoal, excepting that a smaller added (less than a third of the weight of the madder), and the mi diluted with water and boiled for a longer time. The product is ground with a small quantity of chalk or sodic carbonate to neut may be retained by the woody fibre. Madder yields from 33 to 36 Garancin colours are regarded as somewhat less stable than tho from madder; but, if the garancin be well prepared, the colours ar brilliant, and the white ground remains intact. The violets which ever not quite satisfactory, and to obtain a rose colour with it is ve

3. **Pincoffin**, or *Alizarine commerciale*, introduced by Messrs. Manchester, is a garancin prepared and washed with the greatest care, as possible, and heated above 100° by high pressure steam, whereb of brown colouring matter is destroyed or rendered inert. This pure and bright violet tints without requiring clearing, and the oth with it are equally satisfactory.

4. **Garanceux.**—This is a product obtained by treating the dye-houses, which, as already observed, still retains a considerable matter, with sulphuric acid, then filtering, washing, drying, substance thus obtained still dyes tolerably well, and may be used patterns not containing rose or violet tints.

5. **Flowers of Madder** (*Fleur de Garance*) is the name given madder first prepared at Avignon by MM. Julien and Rocquer. pended in water containing a small proportion of acid, partly to sa nates, partly to render the colouring principles less soluble. It is the water for some hours, during which time alizarin and purpu become insoluble, and sometimes a true fermentation is set up. carefully washed, so as to remove only the more soluble matters. being strongly charged with sugar, are subjected to vinous fe subsequently distilling them, a considerable quantity of alcohol is yields about 50 per cent. of this product, which, being free from gu bodies, and especially from the brown colouring principle which yield much finer colours than madder itself. More than half the cultivated at the present day is converted into flowers of madder

6. **Madder Extracts.**—All the products above mentioned whole of the woody fibre of the root, an impurity which prevents

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garancin or sulphuric charcoal, or flowers of madder, is
, as in the preparation of colorin already mentioned,
ers are dissolved out and the woody fibre and other
he solvents used for this purpose are :—
eing almost always the salt employed. The garancin, &c.,
queous solution of alum, the colouring matter precipitated
c acid, and the precipitate collected and washed. The
always contains alumina, but is otherwise very pure, and
n dyeing and calico-printing; but the process is costly,
tities of alum and sulphuric acid, and to recover the alum
separate it from the acid, the mother-liquors must be
en vessels. Moreover, the residue of the madder, being
n prevents its further use in dyeing, is totally lost.
lts.—The alkaline extracts are obtained by repeatedly
ves with solution of caustic soda, carbonate or phosphate of
filtering, precipitating the colouring matter by a mineral
hing and drying. This process is more economical than
ets are much contaminated with resinous and pectous sub-
nd when used for dyeing, yield colours which require very
whereby the depth of the colour is greatly diminished
e improved in quality by boiling them, while yet moist,
en filtering and washing.
e extracts prepared by treating good garancin or flowers
od-spirit, have a fine yellow or yellow-brown colour, and
ney are preserved in the pasty condition. If they are
g matters become so completely enveloped by the resin,
to moisten, and nearly insoluble in water, even at the

Cubian from Madder; E. Kopp's process (Bull. Soc.
) xxxi. 9; Rép. Chim. app. 1861, pp. 165, 223, 276;
his process consists in the treatment of madder with *sul-*
ntially from all the preceding both in principle and in
t of flowers of madder or garancin, but of madder in the
ered as possible, in which, in fact, the colorific principle
nsformed into alizarin or purpurin, these compounds, when
soluble in water containing sulphurous acid.
t on the large scale by MM. Schaaff and Lauth of
The ground madder is macerated for eight or ten hours
t of water containing 2 or 3 per cent. of sulphurous acid;
ed, and the residue is pressed. On mixing the filtrate,
atter, with 3 per cent. of its weight of sulphuric acid, of
ng to 30° or 40° C., purpurin is deposited in large red or
re separated by decantation and filtration, and then washed.
purpurin, heated to the boiling point, gives off carbonic
f alizarin coloured greenish-black by a foreign substance,
y the action of acids on the xanthin of MM. Kuhlmann
arin is collected, filtered, and washed. It may be further
solution in alcohol or wood-spirit.
reen alizarin contains the whole of the sulphuric acid used,
gummy, and other matters extracted by the water from
is used for converting into weak garancin, the madder-
sted by aqueous sulphurous acid and pressed. The mode
me as for transforming fresh madder into garancin.
garancin, which is still acid, but likewise saccharine, is
, and fermented so as to obtain alcohol.
and economical, the quantity of sulphuric acid consumed
ployed in the preparation of ordinary garancin, and the
ng the small quantity of sulphur (or pyrites) required to

the small scale, Kopp obtained from 100 pts. of Alsatian

} dried at 40° C.
ie dried at 40°.
converted into garancin and dried at 100°;

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and he estimates the united colouring powers of these materials as e
that of the madder if employed in the crude state.

It does not appear likely that any other antiseptic substance can be
substituted for the sulphurous acid. Kopp has unsuccessfully tried
arsenious acid, and volatile oils; while the use of antiseptic salts, s
aluminium, mercury, copper, lead, &c. is inadmissible, because the
always contain a portion of the colouring matter, would be contaminat
oxides, and could not then be rendered available for dyeing, in the
or garanceux. (See Hofmann's *Report on Chemical Products and
International Exhibition of* 1862.)

7. **Madder Lakes.**—These lakes, which are obtained by precip
extracts of madder or its derivatives with salts of aluminium, iron, ti
cially with aluminium-salts, possess a degree of fastness which withstan
agents. They are, however, but little used in dyeing and calico-prin
of their high price, but are extensively employed as artists' pigments.
ration of an aluminous madder-lake, see LAKE (p. 466); also *Ure
Arts, &c.*, iii. 15.

The residue of madder treated with sulphurous acid by E. Kopp's
yet exhausted, yields, when washed with boiling water, a yellow liqu
a considerable quantity of colouring matter or of rubian. This liq
a salt of aluminium more or less neutralised, furnishes, on boiling, f
coloured lakes, according as the proportion of aluminium-salt is greate

The same liquid mixed with milk of lime, produces, on boiling, a
(a compound of alizarin and purpurin with lime), which may serve f
double decomposition, other compounds of the colouring matter with
or, if decomposed with heated hydrochloric acid, it will yield the colo
the form of a yellow or brownish-yellow extract resembling colorin (p.

Valuation of Madder. The method usually adopted for ascert
of any sample of madder, is to dye a certain quantity of mordante
weighed quantity of the sample, and compare the depth and solidity of
those produced by the same weight of another sample of known quality

Thibierge (Rép. Chim. app. 1863, p. 157) proposes to estimate
sample of madder by precipitating the alcoholic tincture obtained by
with 100 times its weight of alcohol, with a standard solution of ne
lead. A similar method was proposed some time ago by Basset, who, h
the precipitate. Thibierge states that the colour of the precipitate obt
if controlled by that of the precipitate produced by stannous chlorid
characteristic to detect the presence of any adulteration. The method
with a standard solution of acetate of lead is certainly expeditious, b
be proved that the precipitation is regular and complete, and that t
vitiated by the presence of any foreign body extracted from the madde

Madder is sometimes adulterated with sand, clay, brick-dust, ochre,
oak-bark, logwood, and other dye-woods, sumach, and quercitron-bark.
adulterations are difficult to detect. Those which contain tannin ma
by the usual tests for that substance, since madder contains no tanni
teration is of a mineral nature, its presence may be detected by inciner
quantity of the sample. If the quantity of ash which is left exceeds 10
teration may be suspected.

MADDER, EAST INDIAN. See MUNJEET.

MADREPORES. Calcareous concretions produced by *polypi*,
surface of calcareous ramifications which are fixed at their base, an
numerous pores.

MAGISTERY. A term formerly applied to certain white precipi
basic nitrate of bismuth thrown down on adding water to a solution
nitric acid, was called *magistery of bismuth*.

MAGMA. A precipitate or mass of crystals, or mixture of subst
or pasty state.

MAGNESIA. The oxide of magnesium (p. 754).

MAGNESIA ALBA. A pharmaceutical preparation consistin
of several hydrocarbonates of magnesium obtained by precipitating a solu
salt with an alkaline carbonate. (See CARBONATES, i. 788.)

MAGNESIA NIGRA. An old name for black oxide of manga

MAGNESITE. Native carbonate of magnesium. (See CARBON

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Magnium. Symbol Mg; Atomic weight Mg = 12.
sed with those whose oxides constitute the alkaline earths;
analogous to zinc than to any other element. It occurs in
drate, carbonate, borate, phosphate, sulphate, chloride, and
olid state, sometimes dissolved in various mineral waters
d in sea-water; in a variety of minerals, consisting of
ined with other silicates, as in soap-stone, meerschaum,
hite, hornblende, asbestos, talc, augite, chrysolite,—and
in spinel and zeilanite. It also occurs in the bodies of
as carbonate and phosphate, and in combination with

e compounds of this metal does not date from early times.
of magnesium or *magnesia alba*, as a medicine, was first
the beginning of the eighteenth century. Valentin in 1707
uently found the same earth in the mother-liquor of salt-
Hoffmann, Black, Margraf, and Bergman pointed out the
it from lime, with which it was at first confounded. Davy
etal magnesium, which Bussy succeeded in preparing in a
has since been obtained in much larger quantities by
eville and Caron.
—1. By heating the anhydrous chloride with potassium in
ible. When cold, the contents of the vessel are digested
soluble chlorides are dissolved out, and the metal is left as
melted into globules. (Bussy, Pogg. Ann. xviii. 140.)
the fused chloride. A porcelain crucible is divided in its
by a vertical diaphragm (made out of a thin porcelain
th a cover (filled from a tile), through which the extremities
anic battery are introduced into the two halves of the cru-
heated to redness, together with the cover and the poles,
e of magnesium; and the salt is subjected to the action of a
ments. The negative pole is cut like a saw (*fig.* 427, vol. ii.
m, as it separates, may lodge in the cavities, and not float on
y heavier liquid (Bunsen, Ann. Ch. Pharm. lxxxii. 137).
(Chem. Soc. J. viii. 107), the metal may be much more
mixture of 4 at. chloride of magnesium and 3 at. chloride of
d with greater facility than the pure anhydrous chloride of
mixed in the proper proportion * with a little chloride of
nd electrolysed in Bunsen's apparatus just described, the
being, however, dispensed with, as the metal is heavier than
simple and convenient way of reducing the metal, especially
fuse the mixture in a common clay tobacco pipe over an
rner, the negative pole being an iron wire passed up the
pole a piece of gas-coke, just touching the surface of the
essen.)
, be obtained in much larger quantity, by heating a mix-
le of magnesium, 100 grms. fused chloride of sodium, and
uoride of calcium, with 100 grms. of sodium, to bright
n crucible. The magnesium is thereby obtained in globules,
l nearly to whiteness in a boat of compact charcoal placed
he same material, through which a stream of dry hydrogen
then volatilises and condenses in the upper part of the
l with a flux composed of chloride of magnesium, chloride
calcium, and is thus obtained in large globules. It still,
rtions of carbon, silicium, and nitrogen, from which it may
ation in a current of hydrogen (Deville and Caron, Ann.
tadt has recently prepared magnesium by this process on
mercial purposes.
on the recently fractured surface is sometimes slightly crys-
ated; sometimes fine-grained. In the former case, it is
n the latter, bluish-grey and dull. Its specific gravity is
n); 1·75, according to Deville and Caron. It is about
y be easily filed, bored, sawn, and flattened to a certain ex-
ctile than zinc at ordinary temperatures; it may, however,
t melts at a moderate red heat (Bunsen); melts and
e temperature as zinc (Deville and Caron). It does not

* of magnesium may be evaporated almost to dryness and analysed to
salt present.

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alter in a dry atmosphere, but in damp air soon becomes covered with of magnesium. Heated to redness in the *air*, or in *oxygen gas*, it bur bluish-white light, and forms magnesia. The light of burning mag ably rich in chemical rays, and may be used for taking photograph pure cold *water* buts lowly, *acidulated water* very quickly; when th hydrochloric acid, it takes fire momentarily; strong *sulphuric aci* slowly; a mixture of *sulphuric acid* and *fuming nitric acid* does not dinary temperatures. It burns when heated in *chlorine gas*; also i though with less facility; in *sulphur* and *iodine-vapour* very brilliant unites directly with *nitrogen*, forming a transparent crystallise (Deville.)

Magnesium forms but one series of compounds, in which it is diat

The chloride $Mg''Cl^2$	=	24	+	2.35·5	=	95·
The oxide $Mg''O$	=	24	+	16	=	40

MAGNESIUM, BROMIDE OF, $MgBr^2$, is found in sea-wate salt springs. It is produced by heating magnesium in bromine-vap the vapour over an ignited mixture of magnesia and charcoal. state, it is a white mass of crystalline aspect, which is not fusible and not volatile. It deliquesces rapidly in the air, and dissolves hissing noise and evolution of heat. The solution, which may al dissolving magnesia in hydrobromic acid, yields, by evaporation c crystals containing 3 at. water. When evaporated by heat, it gives drobromic acid, and leaves a mixture of magnesia and bromide of m

MAGNESIUM, CHLORIDE OF, $MgCl^2$, is an ingredient o many salt-springs and other mineral waters. It is produced when in chlorine gas, also by passing a stream of chlorine over an i magnesia and charcoal. This, however, is not a good mode of pr the chloride of magnesium has but little volatility, and does not se the charcoal. Neither can the anhydrous chloride be obtained by di in hydrochloric acid and evaporating to dryness, because it is then by the water, giving off hydrochloric acid and leaving magnesia. preparing it is to evaporate to dryness a solution of magnesia in mixed with sal-ammoniac, and ignite the residue in a platinum cr chloride of magnesium and ammonium is thus formed, from which th before it can decompose the chloride of magnesium; and at a highe anhydrous double chloride is likewise decomposed, giving off s leaving pure chloride of magnesium.

Anhydrous chloride of magnesium is a white translucent mass co flexible crystalline plates, having a pearly lustre, and sharp bitter ta clear liquid at a low red heat. It dissolves readily in water, with c temperature. The *hydrated chloride* is deposited from a hot concen cooling, in needles and prisms containing $MgCl^2.6H^2O$. The crystal quescent, dissolve in 0·6 pts. of cold water, in 0·273 pts. of hot wate alcohol of specific gravity 0·817.

Chloride of magnesium unites with the alkaline chlorides. T $KCl.MgCl^2,6H^2O$, crystallises, by careful evaporation from the last sea-water in rhombohedral crystals.—The *sodium-salt* contains, accor (Compt. rend. xx. 1130), $NaCl.MgCl^2.H^2O$.

MAGNESIUM, DETECTION AND ESTIMATION salts are colourless, unless they contain a coloured acid. The carbo phate, arsenate, arsenite, and many of the organic salts, are insolu most of these salts are soluble in a solution of chloride of ammon others are soluble. The aqueous solutions have a bitter taste. All excepting the ignited metaphosphate, dissolve in hydrochloric acid.

1. *Reactions in the dry way.*—All magnesium-salts contain are decomposed by ignition, leaving a residue of magnesia. Magne before the blowpipe with a small quantity of nitrate of cobalt, lea residue.

2. *Reactions in Solution.*—Solutions of magnesium-salts are *sulphydric acid* or *sulphide of ammonium*. The *fixed alkalis* an produce a white precipitate of hydrate or carbonate of magnesium, i of the reagent, but soluble in ammoniacal salts, especially of chlori If the solution contains ammoniacal salts, no precipitate is formed. to a neutral solution of magnesia, not containing any ammoniacal s

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ble in excess of ammonia; but if the solution previously con-
no precipitate is formed, the magnesium being kept in solution
produced, and even when the original solution is neutral, only
is precipitated, the rest being held in solution in the same
lts are not precipitated by *carbonate of ammonium, ferro-*
or *alkaline sulphates*. *Baryta* or *lime-water* added to the
m-salt forms a precipitate of hydrate of magnesium. This
method of separating magnesia from the alkalis.
f sodium added to a neutral solution of a magnesium-salt pro-
itate of phosphate of magnesium, soluble in nitric or hydrochloric
e then added in excess to the acid solution, a precipitate of
and ammonium, $Mg''(NH^4)PO^4$, is formed, which is flocculent
t soon becomes crystalline, especially on agitation. The same
oduced on adding a soluble phosphate to the solution of a mag-
taining ammonia. It is an extremely delicate test of the
If the solution is very dilute, the precipitate attaches itself in
sides of the vessel. According to Harting (J. pr. Chem.
taining only $\frac{1}{200,000}$ of magnesia, gives a precipitate, after 24
ammonium mixed with free ammonia, provided the latter so-
ated and added in equal quantity. *Oxalic acid* or *acid oxalate*
neutral magnesium-solutions, provided no ammoniacal salts

timation and Separation.—When magnesia occurs in a
any other fixed substance, its quantity may be determined by
igniting the residue, then moistening it with sulphuric acid
er, and expelling the excess of that acid at a low red heat:
then remains, containing 33·7 per cent. of magnesia, or 19·22

s other fixed substances, the magnesia must be precipitated
onia in excess and *phosphate of sodium*. The precipitated
sphate does not settle down at once, but its deposition may be
e vessel in a warm place. Care must be taken, however, not
very hot, as in that case, hydrate of magnesium will be pre-
ry difficult to redissolve. The precipitate, after standing for
ted on a filter and washed with water containing ammonia, as
. It is then dried and ignited, whereby it is converted into
sium, $2Mg^2O.P^2O^5$ or $Mg^4P^2O^7$, containing 36·33 per cent.
ent. magnesium.
als, magnesium may be separated, either by *sulphydric acid*
ium; from aluminium and the other metals of the earths
of ammonium. In precipitating by sulphide of ammonium,
o guard against the simultaneous precipitation of small quan-
hich purpose the ammoniacal liquid should be boiled, before
f ammonia is expelled; any magnesia that may have been pre-
lissolved (H. Rose, Pogg. Ann. cx. 411). For the separation
ganese, see MANGANESE.
nagnesium may be separated by precipitating the former with
. 155).
trontium, magnesium is separated by *sulphuric acid*; from
mmonium, with addition of chloride of ammonium, to prevent the
esia. When, however, the quantity of calcium present is very
e magnesium, this mode of precipitation does not give exact
according to Scheerer (Ann. Ch. Pharm. cx. 36), to convert
nates; dissolve the sulphates in water; carefully add alcohol
ent turbidity is produced; leave the liquid to itself for a few
sulphate of calcium will be completely precipitated, together
sulphate of magnesium; wash the precipitate on a filter with
qual volume of water; then redissolve t in water, add hydro-
d precipitate the lime with oxalic acid and ammonia.
als, magnesium may be separated by converting the bases into
ryta-water. The magnesia is then precipitated in the form of
lphate of barium. The precipitate, after washing, is digested
d, which extracts the magnesia in the form of sulphate; and
e alkalis together with the excess of baryta, is also treated with
cipitates the baryta, and converts the alkalis into sulphates.
e separated from the alkali-metals by means of *mercuricoxide*,

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The solution, from which all metals except those of the alkalis and magnesium been removed, and which must contain no fixed acid, is digested with excess of divided mercuric oxide; the whole evaporated to dryness, and the residue hea drive off the mercury. The magnesium then remains as magnesia, and the alka be washed out with water.

Chancel (Compt. rend. 194) recommends the following method. The magn precipitated from the solution containing sal-ammoniac and free ammonia, by *pho of ammonium;* the filtrate is evaporated to dryness; the residue carefully ign expel ammoniacal salts; then redissolved in water; and the solution is mixe nitrate of silver and a slight excess of carbonate of silver. After filtering phosphate of silver (and chloride, if the alkalis existed in the solution as chloride excess of silver is removed from the filtrate by hydrochloric acid, and the alka estimated as chlorides.

4. *Atomic Weight of Magnesium.*—Berzelius found that 100 pts. of ma dissolved in pure sulphuric acid and ignited, gave 293·85 of sulphate of magn $Mg''SO^4$, whence the atomic weight of magnesium would be 25·24, a result to according to later experiments.

Scheerer (Pogg. Ann. lxix. 135), by determining the quantity of sulph barium produced from a given quantity of sulphate of magnesium, found for mag the number 24·2. The results of Svanberg and Nordenfeldt (J. pr. Che 473), obtained by the decomposition of oxalate of magnesium ($Mg''C^2O^4.2H^2O$ it 24·7; those obtained by converting a known weight of magnesia into s gave it as 24·74; whilst those of Marchand and Scheerer (Ann. Ch. Pharm 219), obtained by igniting the native carbonate (magnesite), gave the number Dumas (Ann. Ch. Phys. [3] lv. 129) attempted to determine the atomic we magnesium by precipitating the chloride with nitrate of silver, but he fou greatest difficulty in obtaining the chloride free from magnesia. The mean of experiments gave $Mg'' = 24·6$.

The mean of all these results is 24·32, but those of Marchand and Schee generally regarded as the most trustworthy. Moreover Scheerer has lately sho his method of separating calcium and magnesium above given (p. 753), th specimens of magnesite used by himself and Marchand in their determinatio tained small quantities of calcium not previously detected. He therefore co that the number 24·04 found in those experiments was rather above than be truth. On the whole, then, the atomic weight of magnesium may be regarded

MAGNESIUM, FLUORIDE OF. Obtained as a white tasteless pow treating the carbonate with hydrofluoric acid, or mixing the sulphate with fluo potassium. It is insoluble in water and nearly insoluble in acids.

MAGNESIUM, FLUOBORIDE OF. See Borofluorides (i. 634).

MAGNESIUM, FLUOSILICIDE OF. See Silicofluorides.

MAGNESIUM, IODIDE OF. Obtained by evaporation of its solutio difficultly crystallisable hydrate, which deliquesces in the air, and when heate off hydriodic acid and leaves pure magnesia.

MAGNESIUM, NITRIDE OF. Mg^3N^2.—Deville and Caron (Comp xliv. 394), by distilling impure magnesium, obtained a black residue, and a di of magnesium covered with small transparent needles, which easily decompose formation of magnesia and ammonia, and therefore contained a nitride of magn Briegleb and Geuther (Ann. Ch. Pharm. cxxiii. 228) have obtained th compound, in the amorphous state, by igniting metallic magnesium in ammoni nitrogen gas; the latter method giving the purest product. Nitride of mag thus prepared is a greenish-yellow amorphous mass, becoming brownish-yello hot. Heated in dry oxygen gas, it oxidises to magnesia, with vivid incandescen is decomposed by air and water, the reaction in the latter case being violent to make the water boil. Acids both dilute and concentrated, with the excep strong sulphuric acid, form ammonium- and magnesium-salts, even in the cold; sulphuric acid, only when heated, and with evolution of sulphurous anhydride nitride heated in hydrochloric acid gas, yields chloride of ammonium and chlo magnesium; in sulphydric acid, the corresponding sulphides. Carbonic anhydr dry carbonic oxide decompose it, at the heat of a strong air-furnace, with sep of carbon and formation of cyanogen. When vapour of pentachloride of phosph passed over nitride of magnesium heated in a stream of nitrogen, the nitride verted into a greyish-white substance, probably P^3N^5, according to the equation

$$6PCl^5 + 5Mg^5N^2 = 15MgCl^2 + 2P^3N^5.$$

When nitride of magnesium is heated to 160° –180° in a sealed tube with oxyc

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xcess of oxychloride is distilled off, there remains a residue
dissolves completely in water, with great evolution of heat,
gives, with acetate of barium, a precipitate of metaphosphate
cohol and iodide of ethyl do not act on nitride of magnesium,

XIDE OF. *Magnesia.* MgO.—This earth, which is the
agnesium, is produced in the form of a white amorphous
n burns in the air or in oxygen-gas, and remains in the same
, nitrate, or any other salt of magnesium containing a volatile
. It may be obtained crystallised in cubes and regular octa-
ing amorphous magnesia in a stream of hydrochloric acid gas
Pharm. cxx. 280; Jahresb. 1861, p. 7); also, according to
n (Ann. Ch. Pharm. cxx. 283), by strongly igniting a mixture
n and an alkaline sulphate in a platinum crucible, so that the
ne heat may crystallise from the fused alkaline sulphate. A
l ferric oxide, strongly ignited in hydrochloric acid gas, yields
ack octahedrons of magno-ferrite, $MgO.Fe^2O^3$ or $\left.\begin{matrix}Mg''\\(Fe^2)^{vi}\end{matrix}\right\}O^4$,
ular octahedrons of magnesia containing a small quantity of
periclase, a mineral consisting of magnesia with 1 part in 25
ccurs disseminated through ejected masses of white lime-stone,
crystals, on Monte Somma.
gnesia is prepared by gentle but prolonged ignition of the car-
hite, very bulky powder, of specific gravity 3·07 to 3·200,
a pottery-furnace to 3·61 (H. Rose). It melts only at the
s, as in the oxyhydrogen blowpipe flame, to which it imparts
then converted into a sort of enamel, which scratches glass
). It is tasteless and inodorous; changes some of the more
s, as that of moistened red litmus paper, like the alkalis; it
rtially decomposed by potassium at a white heat. It is very
r; in 55,368 pts., either cold or boiling, according to Fre-
n. lix. 117), the solution having a faint alkaline reaction.
m, MgH^2O^2, occurs native in rhombohedral forms, as brucite
ed as a white powder on adding potash, soda, or baryta-water
of a magnesium-salt.

LPHIDE OF. A sulphide of magnesium is obtained, mixed,
by heating a mixture of charcoal and sulphate of magnesium.
ed by adding to the preceding mixture, an alkaline persulphide,
te of sodium with excess of sulphur. According to Frémy,
s easily produced by passing the vapour of sulphide of carbon

are not precipitated by alkaline sulphides, but on mixing sul-
h sulphide of barium, sulphate of barium is precipitated, and
remains in solution. Sulphide of magnesium is likewise
hydric acid gas in excess into water containing magnesia in
of sulphide of hydrogen and magnesium is then formed, which
, into sulphydric acid, and a white gelatinous mass of sulphide

m forms double salts with sulphide of carbon, and with the

n is decomposed, by the continued action of water, into mag-
l. The presence of that acid in mineral waters may, perhaps,
xistence of sulphide of magnesium in the strata through which
(Pelouze and Frémy, *Traité*, ii. 286.)

HYL. $Mg(C^2H^3)^2$.—When iodide of ethyl is added to
ined in a strong narrow glass tube, an action immediately
ith rise of temperature, and evolution of a considerable
g ethylene, and apparently also ethyl and hydride of ethyl.
ooled with cold water, be sealed and heated for some hours to
s solidify to a white mass, which, when subsequently distilled,
of magnesium, and a distillate containing undecomposed iodide
m-ethyl, which may be separated by fractional rectification.
colourless liquid, having a strong alliaceous odour, and boiling
than iodide of ethyl. It takes fire in the air, and decomposes
Cahours, Ann. Ch. Pharm. cxiv. 227, 354; Jahresb. 1859,

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p. 416. See also Hallwachs and Schafarik, Ann. Ch. Pharm. cix. 1859, p. 407.)

Magnesium-ethyl forms a finely-crystallised double salt with iodide probable formula, MgC^2H^5I. (Wanklyn.)

MAGNESIUM-METHYL is produced by the action of magne of methyl in a manner similar to the above. It is likewise a mobile liquid, which instantly takes fire in the air, and quickly decomposes wa tion of marsh gas and separation of magnesia. (Cahours.)

MAGNETIC IRON ORE. Native ferroso-ferric oxide (iii. 337)

MAGNETIC PYRITES. Ferroso-ferric sulphide (iii. 401).

MAGNETISM. It has been known from very early times, that t oxide of iron, or ferroso-ferric oxide (Fe^3O^4) possesses, at certain point called poles, the power of attracting small pieces of iron. The Gree mineral the name of *magnetes* (μάγνητης), from the village of Magn near which it was found in considerable quantity: hence the name M plied to the branch of science which treats of this peculiar kind of att the various phenomena related to it.

The attractive power of the natural magnet may be communicated t by contact, the attractive power thus developed continuing, in soft iron, the contact lasts, whereas, in hard iron, and more especially in steel, it separation from the natural magnet. A bar of steel rubbed lengthw constant direction, with the pole of a natural magnet, becomes itself a of attracting iron, and imparting its power in like manner to other bar

Another mode of imparting magnetism to iron or steel is by the acti current or discharge, as already described in the article Electricity (ii bar, placed within a helix of wire through which an electric current is a permanent magnet. Lastly, as we shall presently explain more par of iron or steel may be rendered magnetic by placing it in a certain po to the earth.

The properties of magnets are the same in whatever manner their developed.

There are only two other metals, viz. nickel and cobalt, in which the can be conspicuously developed by the means above mentioned: in ni siderable, but much less powerful than in iron; and in cobalt, still l bodies are, indeed, more or less susceptible of magnetic influence, but effects only when subjected to very powerful electric or magnetic forces cases, the mode of manifestation is very different from that which is ex See Diamagnetism (p. 770).

Distribution of Magnetic Power.—In a magnetised steel bar, as in the the attractive power is not uniformly distributed, but is more or less certain points called poles, situated at or near the ends of the bar, w nishes with greater or less rapidity and regularity towards an interm rather line, called the median line, generally in the middle of the bar shown by rolling the bar in iron filings, which then attach themselves in the ends, leaving the middle bare, as in *fig.* 716. If the two poles have

Figs. 716.



Fig. 717.

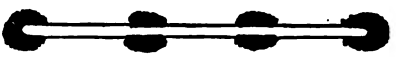


Fig. 718



power, and are situated at equal distances from the ends, and the po from each of them at the same rate towards the middle, the bar is said

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, is not always the case. Sometimes a magnet exhibits
wn in *fig.* 717.

ended Magnetic Bar.—When a regularly magnetised steel
re of gravity from a thread without torsion, or supported by
t, as in *fig.* 718, so that it can move freely in a horizontal
ar position with respect to the poles of the earth, one end
y towards the north, the other to the south. A bar-magnet
magnetic needle, though the so-called needle is some-
several pounds. Small needles are sometimes made of flat
, like that represented in *fig.* 718.
h the bar in its position of equilibrium makes with the
ferent on different parts of the earth's surface, and varies
ent times. In some parts, the suspended magnet points
London, at the present time (1864), the direction is north-
sition of equilibrium making an angle of 20° 45′ with the

g through the two poles of the needle is called the mag-
lace, and the angle which it makes with the geographical
ination.
suspended bar always points towards the north, the other
ar be placed exactly in the opposite position, it may remain
f unstable equilibrium; but the slightest disturbance will
former position, in which, after a certain number of oscil-
. The two ends of the bar are accordingly designated as
s respectively.* Every regularly magnetised piece of iron
and two only, which are not interchangeable.
nstead of having its movements restricted to a horizontal
centre of gravity, in such a manner that it can move freely
self, not only in the magnetic meridian, but likewise at a
horizon, which also differs according to the locality, and
different times. In London, at the present time, a freely
places itself at an angle of 68° 15′ to the horizon, with its
nagnet, suspended so as to exhibit this inclination, is called
e angle of inclination is called the dip.
dle dips throughout the greater part of the northern hemi-
hroughout the greater part of the opposite hemisphere, and
here is a line not deviating greatly from the earth's equator,
dip, but stands horizontally. In short, as will be seen
ements of a freely-suspended needle in different parts of
be accounted for by regarding the earth as a great magnet,
xhibiting southern, and the southern hemisphere northern
AGNETISM, TERRESTRIAL.)

NETIC ATTRACTION AND REPULSION.

iron is attracted indifferently by either pole of a magnet,
served, that the attraction is mutual, so that, whichever of
ve towards the other; and if both are movable, they will
velocities which are inversely as their masses. Hence, if a
or steel be presented to either pole of a magnetic needle,
ds it. But, when a magnetised bar is presented to the
north pole of the one attracts the south pole of the other,
south pole attracts a north pole, but repels a south. The
traction and repulsion is then exactly similar to that of
sion (ii. 376), viz. *Similar magnetic poles repel, dissimilar*
Hence, to determine whether any piece of iron or steel is
icient to present the several parts of its surface to a deli-
needle: if every part attracts the needle, the piece of iron
rity; if, on the other hand, some parts attract, while others
e, the iron is shown to be magnetic, and the number and
determined.
epulsion are not prevented by the interposition of any sub-
of magnetism. If a magnetic needle be deflected from its
a piece of iron, or another magnet, near it, and allowed to

, and commonly by French authors, the pole which points northwards
ral), and that which points southwards the north pole (*pôle boréal*)
this confusion, Faraday speaks of the pole which points northwards

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settle itself in its position of equilibrium, that position will not
interposition of a screen of paper, wood, glass, copper, &c.; but, i
interposed, the needle will immediately take up a new position, th
magnetic forces being altered by the interposition of the iron.

*The force of magnetic attraction and repulsion varies inversel
the distance between the poles or centres of action.*—By the term
understand the point of application of all the forces exerted by o
on any point of the other. It is evident, then, that the poles mu
according to the distance between the magnets; but unless the ma
together, the distance between their poles will not differ sensib
exists when the magnets are placed so far apart that all the ac
regarded as parallel. The poles, understood in this sense, do not of
the points of strongest attraction, which are generally at the ends
they are nearer to those points in proportion as the magnetic po
rapidly from the ends towards the middle.

This law of magnetic action may be demonstrated in three ways:
Balance.—The construction of the magnetic torsion-balance is sim
described (ii. 380) for the measurement of the electric forces, the s
replaced by a magnetic needle, and the shellac stem by a bar-mag
experimenting to determine the law of magnetic action with re
exactly similar to that described at page 381, vol. ii., for meas
electric attraction and repulsion.

2. *By the Method of Oscillations.*—Suppose a magnetic needle t
bar-magnet, with its centre on the prolongation of the axis of that m
place itself in the direction of that axis, and if disturbed from
oscillate backwards and forwards, and ultimately settle in its origin
brium. Now the oscillations of the needle thus vibrating under the i
attraction, are regulated by the same laws as those of a pendulum
influence of gravity, that is to say, *the squares of the times of oscilla
the attracting forces.* Supposing then the power of the magnet an
constant during the experiment, the diminution of the attractiv
distances may be measured by counting the number of oscillations w
forms in a given time at different distances. It is necessary to observ
the oscillations of the needle are determined by the magnetic force
as by that of the magnet, the terrestrial force must be either compen

To simplify the calculations as much as possible, the experiment
with an *astatic needle*, that is to say, a system composed of two
equal power, joined together parallel to one another, but with the
directions, by a small piece of straw or copper wire passing throu
gravity (ii. 443); such a combination will evidently place itself
positions relatively to the magnetic meridian, because the magneti
acts on the two needles composing it with equal force but in opposi
let one of the poles of such a needle be brought near the contrary p
of such a length that the action of its farther pole may be left ou
distance between the poles of the magnet and needle is then t
needle made to vibrate, and the number of its oscillations perform
counted. The needle is then removed to a greater distance and
repeated. If then m and m' are the magnetic forces at the distance
corresponding numbers of oscillations in the same time; we have
Now experiment shows that the quantities n, n' d, d' are relat
$n : n' = d' : d$, that is to say, the number of oscillations in a given
as the distances; consequently

$$m : m' = d'^3 : d^3.$$

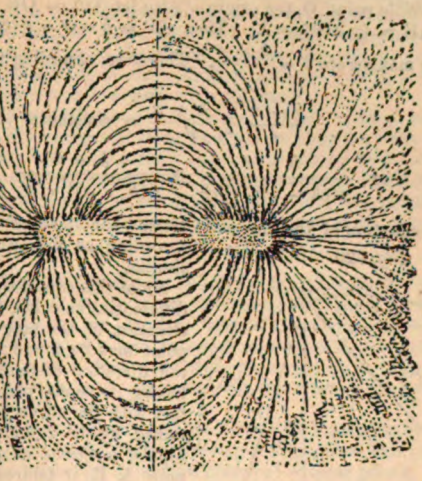
The same result may be attained by the use of a needle not ren
N be the number of oscillations which it makes in a given time un
the earth's magnetism alone; n the number performed in the same
influence of the terrestrial force and that of a magnet placed at a ce
the needle in the magnetic meridian; and n' the number perfor
when the magnet is removed to a greater distance. If then the ma
earth, and of the magnet at the two distances mentioned, be de
respectively, we shall have

$$N^2 : n^2 = F : m + F$$
$$\text{and } N^2 : n'^2 = F : m' + F$$
$$\text{therefore } n^2 - N^2 : N^2 = m : F$$
$$\text{and } n'^2 - N^2 : N^2 = m' : F$$
$$\text{and finally } m : m' = n^2 - N^2 : n'^2 - N^2.$$

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Magnetic Curves.—Place a bar-magnet under a sheet of stiff
fine iron filings on the paper through a gauze sieve. These
elves round the magnet in peculiar curves (*fig.* 719), radiating

Fig. 719.



oles. Now these curves are clearly the graphic expression of
action and repulsion with regard to distance: for each of the
e of the magnet becomes itself a small magnet, the poles of
a position determined by the resultant of the forces exerted
les of the magnet; and this position of equilibrium varies
of the filing from the two poles respectively. In fact, a small
n any part of the paper, will settle itself in the direction of a
ssing through that point. If placed on any point of the
f the magnet, it will take up a position parallel to that axis
nsecutively with those of the bar-magnet; at any point on the
entre of the magnet at right angles to its axis—every point
nt from the two poles—the needle will place itself parallel to
les in the contrary direction; and in any intermediate position,
f obliquely to the magnet, its inclination increasing with the
from the two poles.

neration of the magnetic curves—or, what comes to the same
tion—can be determined, the law of force with regard to
from it. The curves may be obtained in a state convenient
ing them over a plate of glass in the manner above described,
t of paper covered with gum or starch paste. In this manner
the paper, and the curves may be measured.

ts of the curves formed by the joint action of two magnetic
imilar, on iron filings or infinitely small magnets, Roget has
law: *The difference of the cosines of the angles formed with the
ning the two poles) by lines drawn from these two poles to any
is a constant quantity, the two angles being taken on the same*

n instrument for tracing the curves by continued motion,
and has also given the following method for describing them

centre, and with any radii whatever, describe two circles;
eets both these circles; divide the whole length into any
d project each point of division perpendicularly on the two
indefinitely prolonged be then drawn through the centre of
he points thus determined upon it, these radii will intersect
nging to the curves.

are of contrary name, the curves are said to be *converging*
vilinear diagonals in the direction of the magnetic axis of the

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quadrilaterals formed by the intersection of the rays. If on the other hand th poles are of the same name, the curves are said to be *divergent*, their direction that of the curvilinear diagonals perpendicular to the former.

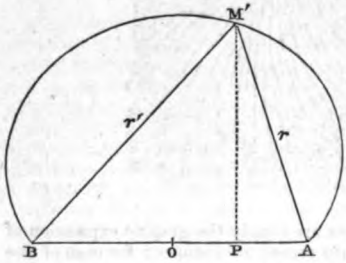
Now let A, B (*fig.* 720) be the two magnetic poles, M a point of the curve co-ordinates, referred to two rectangular axes, are x and y. Let AB be the of x, and its middle point, O, the origin. Also let $OA = OB = h$; $AM = r$; r'; angle $MAB = i$; $MBA = i$. Then $AP = h - x = r \cos i$; therefore co $\frac{h-x}{r}$; in like manner $\cos i' = \frac{h+x}{r'}$. Therefore, according to Roget's law,

$$\frac{h-x}{r} \pm \frac{h+x}{r'} = \text{constant};$$

$$\text{or } \frac{h-x}{\sqrt{(h-x)^2+y^2}} \pm \frac{h+x}{\sqrt{(h+x)^2+y^2}} = \text{constant}.$$

This is the equation of the magnetic curves, the upper or lower sign being according as the two poles are opposi similar.

Fig. 720.



From this equation, by the processes differential calculus, the expression of t clination of the tangent to the curve point may be found; and as this tang the direction assumed by a magnetic having its centre placed over the point o tact with the curve, which direction is mined by the resultant of the attractiv repulsive actions exerted upon it by th poles A, B, it follows that the value o inclination, properly expressed in ter the distance of the point of contact fro two poles, will give the law of variati the intensity according to the distance. When these calculations are ma is found, in accordance with the results of the other modes of measurement described, that the intensity of the force of magnetic attraction and repulsion inversely as the square of the distance. (See De La Rive, *Traité de l'Electricité*, t note D, p. 592.)

Comparison of the Power of different Magnets. Distribution of Magnetism

The old method of comparing the power of magnets, or of different parts of the magnet, consisted in ascertaining the weights which they were capable of suppo This method, however, can give only a rough approximation to the truth, inasm the weight which a magnet can support depends in great measure on the man which the weight is applied, and on the rate at which it is increased. When the with which a magnet is loaded is very gradually increased, it is found to be capa supporting a much larger weight than could be supported by it if applied all at

Much more exact results are obtained with the torsion balance and by the met oscillations, both of which methods have been applied to this purpose by Coulom

To compare the force of two or more magnets by the torsion balance, these m are introduced successively through the hole m (*fig.* 373; ii. 380) and the nee the balance is kept at a constant angular distance by twisting the thread through ent angles, which are to one another as the forces to be overcome. When the m of oscillations is employed, the magnets are placed successively at a constant di from the needle, this distance being so great that they cannot alter the distribut its magnetic power.

Magnetic Moments.—Another mode of comparing the power of magnets is to each of them successively in a small stirrup suspended from the thread of the to balance, so that the magnet may remain in the magnetic meridian when the thread twisted. The thread has then to be twisted through different degrees, so as to for each magnet the same angle of deviation from the magnetic meridian. The of torsion thus found represent what Coulomb calls the magnetic moments several bars. It is evident that the magnetic moment depends both on the ma intensity of the bar, and on the distance of its poles from the axis of suspension.

Distribution of Magnetism.—To measure the relative attractive or repulsive exerted by the different parts of a bar-magnet, Coulomb introduced a vertical w rule into the glass case of the torsion-balance, in such a position that it touch needle of the balance which rested in the magnetic meridian when the threa

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this rule was a vertical groove in which the magnet to be
p and down, so as to bring the several parts of its length
needle of the same name as the half of the bar which was
e was thereby repelled; and to bring it back to its original
be twisted through a certain angle, which measured the
ie bar was then shifted in the groove, so as to bring another
pole of the needle, and a similar experiment was made.
y close to the needle, it is only the points very nearly on a
can exert any sensible influence over it, those which are
e or below, acting too obliquely.
f oscillations to the same purpose, a small needle, magne-
its magnetic state may not be altered by the action of the
r different parts of the bar. Denoting by m, m' the magnetic
oints, and by N, n, n' the number of oscillations made in
ience of the earth alone, and under this influence added to
e bar under consideration, we find, as on page 758,

$$m : m' = n^2 - N^2 : n'^2 - N^2.$$

ives directly the relative magnetic intensity of any part of
emities, for which the intensities found by direct experi-
der to give the true force at these points, as compared with
erved at these extreme points would evidently be double
o be, if the magnet were prolonged, so as to present, beyond
equal magnetic force with those which are within them, as
art of the bar.
hese methods may be represented graphically by erecting,
rizontal line representing a magnetised bar, perpendiculars
al to the intensities observed at these points. The ends of
like that represented in *fig.* 721.
kable that for all rectangular or cylindrical bars whose
ds 20 centimetres (or 8 inches) the form of this curve, that
e distribution of the magnetism, is the same, excepting that
the middle, where the magnetic power is little or nothing,
eater or smaller space according to the length of the bar.
that is to say, the points of application of the resultants of
exerted on each half of the magnet by an infinitely small
gnetic element, placed at such a distance that all the lines
be regarded as parallel, correspond with the centres of
ie surfaces enclosed by the curves of intensity. Hence
iets of equal force and longer than 20 centimetres, the
uated at the same distance from the extremities: this
ording to Coulomb's calculation, is about 4 centimetres
ches). In shorter bars they are situated at about two
distance from the centre to the ends.
ding results apply only to magnets whose length is very
portion to their transverse dimensions, and in which the

at is, prismatic or cylindrical, and the magnetisation likewise
needles, the poles are much farther from the extremities.

Magnetic Induction.

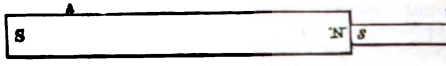
oned that a piece of iron or steel placed in contact with a
tural or artificial, becomes itself a magnet. This action
with diminished intensity, at a distance, and is not pre-
of non-magnetic bodies. This effect is called magnetic
cording to which it takes place is precisely analogous to that
), viz. that *The extremity of the iron or steel nearest to the*
mes a pole of contrary name, and the farther extremity a
he inducing pole. Thus, suppose a bar of soft iron to be
orth pole of a magnet; on presenting a magnetic needle to
edle will turn its south pole to the bar, showing that that

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end has become a north pole. If the bar be detached and the ind moved, the polarity of the bar is immediately destroyed, and the n normal position; and if the south pole of the magnet be now plac or near to the end of the bar, the needle will turn round and presen the farther extremity. The polarity of the end of the bar which the inducing magnet, cannot easily be tested in a similar manner, contrary action of the inducing pole; but if a short steel bar be soft iron, and left in contact with the magnet for a few seconds, it v rated, exhibit two poles, that which has been in contact with the p magnet being a pole of contrary name.

Moreover, the iron or steel thus rendered magnetic by induction wi similar manner on any other piece of iron or steel in its neighbo polarity in it, if previously unmagnetised, and altering the distribu of its polarity if previously magnetised. Consequently, just as th of a charged body is intensified by developing electricity in a neigh (ii. 385) so likewise may the polarity of a magnetic bar be strengt magnetism in a neighbouring piece of iron. Thus, suppose a bar of placed in contact with the north pole of a steel magnet, A, in the n in *fig.* 722, B will then become a magnet with its poles disposed si

Fig. 722.



A, and will act upon A, just as if B were the original magnet, and A iron. The original polarity of A will therefore be strengthened; and that a steel magnet is rendered more powerful and capable of su weight, by leaving pieces of soft iron in contact with its poles.

It will be easily understood, from the preceding exp'anations, th unmagnetised iron by the magnet is not an isolated phenomenon, l cular case of the general law of the attraction between similar ma is also easily shown by experiment. Suspend a piece of iron, a ke the north pole of a bar magnet; then bring the north pole of a secon with the first; the key will be held with greater force than befor magnets polarise it in the same way. Now turn the second magn its south pole in contact with the north pole of the first; the ke drop off, because the second magnet induces in it a polarity con first, and reduces it to the condition of unmagnetised iron.

The case is, however, different if the two magnets act at oppos magnetised iron. Thus, let two magnetic poles P, P′, (*fig.* 723) be with the two ends of a bar of soft iron B, not more than two or th the poles P, P′, are similar, the iron will not be held up by them, b

Fig. 723.

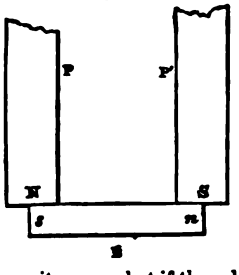


Fig. 724.



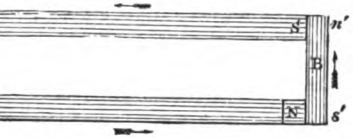
polarise it in opposite ways; but if the poles P, P′ are dissimilar, the will conspire, and the piece of iron will be held up with greater for by either of them alone. Hence also a magnet bent in the form o 724) will hold a piece of iron placed across its poles, with great magnet of the same size and intrinsic magnetic force; and by u such horse-shoe magnets with their similar poles together, great pow

Another fact tending to show that the attraction of iron by a ma ceded by magnetisation of the iron is, that very hard steel, which a slowly is scarcely attracted by the magnet.

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poles *s*, *n*, of a piece of iron laid across the poles of a horse-
en its polarity; in fact it is the constant practice to keep
not in use, with a piece of soft iron—thence called a keeper
ike manner the best way of preserving the power of bar

Fig. 725.

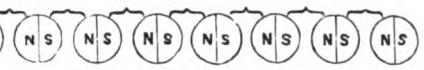


em side by side in a box, with their poles pointing opposite
ed across them (*fig.* 725).

cular Constitution of Magnets.

omena hitherto considered are consistent with the sup-
larity resides in one half of the magnet, and the south
kind of polarity gradually increasing in intensity from
ds. But there are certain effects which show that mag-
resides in molecules, not in masses. Take a steel wire
break it in the middle. It will be found that each half
ng a north and a south pole, with a median line between
be again divided in the middle, four complete magnets
ving a north and a south pole, and so on, to whatever
carried. This result is easily intelligible, if we suppose the
ection of molecules, each having a north and a south pole,
inting the same way. It is easy to see that, in such a row of
e opposite polarities towards the middle of the series will

Fig. 726.



only those of the two extremities will be perceptible; but
ed at any point, each half will exhibit polarity similar to
uch a series of polarised particles really acts like an ordi-
by partly filling a glass tube with steel filings, and passing
t five or six times along the outside of it in one constant
shake the tube. The individual filings will thus be mag-
mn, if presented to a magnetic needle, will attract and repel
ary bar magnet, exhibiting a north pole at one end, a south
larity in the middle; but on shaking the tube, or turning
hem in again, so as to destroy the regularity of the arrange-
y will disappear.
to observe that, in a single row of particles, such as that in
ual magnetic polarity, the resultant polarity would be exhi-
remities. Now, this is not what is actually observed in
e must be attributed to the lateral actions of the particles
ng the magnet, one on the other.

rocesses of Magnetisation.

d of the molecular constitution of magnets, it is clear that
must consist in polarising each separate molecule of which
, when a bar of soft iron is placed in contact with a mag-
icles become polarised by the direct influence of that pole,
thus the polarisation is rapidly developed all along the bar.
er a certain resistance, called the coercive force, to the
les, so that the development of magnetism in them, espe-
proportion to the hardness of the temper. Thus, when a
in contact with the north pole of a magnet, the nearer
mes a south pole, but the farther end shows no polarity at
wever, formed at a short distance from the south, and near
ole, just as if the bar were divided at that point, and the
acted like a separate magnet on the portion beyond. These

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poles gradually advance along the bar, a feeble south pole appearing
the farther end, succeeded, after a while—if the bar is not too long—
the bar then appearing regularly magnetised. If, however, the bar is
made of very hard steel, it never attains this regular magnetisation,
series of alternate or *consecutive* poles, which never reach its farther e
coercive force may, however, be more or less overcome, and regular
facilitated, by striking the bar with a piece of metal, so as to make it
its particles into vibration.

It is obvious that the polarisation of the whole series of particles con
will be accelerated by laying it between two bar magnets, with their
facing one another, or across the poles of a horse-shoe-magnet, the mag
taking place in two directions at once, and both tending to the same re

Another process more generally adopted, consists in passing the po
from one end to the other of the piece of steel to be magnetised, repeat
several times and always in the same direction. Each particle of th
brought successively under the influence of the magnet, and it is
magnetic power of the bar increases with the number of strokes up to
after which no further increase takes place. The polarity imparted to
the magnetic pole approaches it, is reversed when the pole passes ove
polarity finally imparted to the bar is that which corresponds to the las
inducing magnetic pole. If, for example, the steel bar be rubbed with t
a magnet, the end first touched will be a north, and the other end, by w
leaves the bar, will be a south pole. It is not very easy to understand
by repeating the friction, inasmuch as the polarity imparted by each str
at the commencement of the next. Possibly the coercive force of th
come by the disturbance consequent on the continued reversal of the po
the same manner as it is by vibration.

Greater power may be obtained by a combination of the two methods
namely, by laying the bar to be magnetised between the opposite poles
or those of a horse-shoe-magnet, then, taking two other bar magnets, on
bring down their opposite poles on the middle of the bar to be magnetis
them at an inclination of 25° or 30°, draw them outwards, with a
towards the extremities of the bar. Ten or twelve strokes given in th
always in the same direction, will give to the bar, if not very large, as
power as it is capable of retaining. It is of course necessary that t
movable magnet which touches the bar, should be of the same name
fixed magnetic pole towards which it is made to move. This metho
Duhamel, and called the *method of single touch*, is the best for magn
needles, and bars of no great length and thickness, in which regular
magnetism is desired rather than great attractive power; but for ma
thick bars, especially when it is desired to give them their full power
method of Æpinus, called the *double touch*, is to be preferred. The bar
two powerful magnets as in the preceding method, and likewise rubbed wi
poles of two magnets; but instead of drawing these poles from the mid
opposite ends of the bar, they are tied together, with a piece of cork o
them to keep them at a certain distance apart, and made to travel toge
bar, first one way and then the other, beginning and leaving off in the m
shoe-magnet may be conveniently used instead of two bar-magnets tied
this method it is likewise easy to magnetise two steel bars together, nan
them parallel to one another, with soft iron keepers across their extremitie
and passing the two magnetic poles several times round the rectangl
beginning in the middle of one of the bars, and leaving off at the same
as indeed in all methods of magnetising, the bars, after having been r
number of times on one side, should be turned round and rubbed in th
on the other.

In both these methods, when two movable magnets are employed, the
any particle acquires while outside the magnetic poles, is reversed
motion it is brought between them. Now the advantage of the doubl
consists in this, that the two poles of the movable magnet or magnets a
only a small distance, so that the sum of their actions on a particle betwee
as great, and the difference of their actions on an outside particle as sm
This very circumstance, however, by developing powerful magnetism
particular part of the bar, creates a tendency to the formation of consecu
the steel is very hard. Hence, as already observed, the single touch me
adopted where regularity of magnetisation is the main object in view.

Magnetisation by the Electric Current.—Very great magnetic power m
in soft iron by placing it within a long coil of wire through which an

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ars may be magnetised in the same way, but the magnetism
ut feeble, apparently because there is a want of vibratory
ie coercive force. The magnetisation may indeed be
es, by striking the bar so as to make it ring while it is
urrent; but the best mode of magnetising steel bars by the
the bar through a short movable coil of wire, then fix it
ctro-magnets, the coils of which are connected with the
one continuous circuit, and, having made the connection
e movable coil backwards and forwards along the whole
it at the same time against its surface, so as to excite a
icles. In this way very powerful and regular magnetisation
Traité de Physique, iii. 608). It is easy to see, however,
sation requires rather complex apparatus, especially as, to
sm in soft iron requires a very long coil of wire passing
, and consequently a powerful battery of several cells to
he circuit. In most cases, therefore, the simpler methods of
and double touch are found more convenient.

rial Induction.—If a bar of soft iron, destitute of magnetism
e held in the line of the magnetic dip, or in the vertical
titudes does not differ greatly from it, its lower extremity
red north, and the upper, south polarity. On reversing the
o reversed, the lower extremity being still a north pole.
nductive action of the earth, the northern hemisphere of
rved, like the south pole of an ordinary magnet.

el held in a similar position, does not immediately exhibit
striking it several times with a key or a hammer, it be-
ised with its north pole downwards. In this way, perma-
ined without the use of other magnets or of the electric
el may be greatly augmented by resting it on a bar of iron
oth. Scores by obtained powerful magnets by the following
was placed vertically and struck, and having thus acquired
tic power, it was placed successively on each of two steel
ne inch wide, these bars being also placed vertically and
Six smaller bars of steel 8 inches long and half an inch wide
similar manner, by resting them vertically on one of the
g them, by which treatment they acquired in a few minutes
wer. Lastly, the six small bars were joined two and two
y means of soft iron keepers, and rubbed with the others
uch method. By this treatment they were found to be

agnetic action of the earth, all bars of iron, such as railings,
standing for a length of time in a vertical position, become
their lower ends in the northern hemisphere acquiring
gnetism of the native black oxide of iron has doubtless
me causes, the very different magnetic power exhibited
ing partly attributable to the different positions of the
the line of the magnetic dip, that is to say, the line of the
magnetic forces.

which influence the Power of Magnets.

ocess of magnetisation adopted, there exists, for each bar or
force which cannot be permanently exceeded; this limit,
of saturation, depends essentially on the coercive power
h the bar is made.

, be magnetised beyond their point of saturation, and do not
he time occupied in returning to it depending upon various
nges of temperature, the neighbourhood of other magnets,
earth, &c. To ascertain whether a bar has been magnetised
nt to remagnetise it, in the same direction, with magnets
were used in magnetising it originally; if it thereby acquires
, and this power disappears after a while, we may conclude
had previously been attained.

hape.—With regard to size, Coulomb found: 1. That the
rated magnets of the same substance and of similar form are
cubes of their like dimensions. 2. That, in cylindrical
gth, the magnetic power is sensibly proportional to the

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diameter. 3. The time of oscillation of a bar having a rectangular breadth is *l*, thickness *e*, and length 2L, is given by the formula:

$$t = me\sqrt{l} + n\,L,$$

in which *m* and *n* are constants, depending on the nature and hardness

With regard to form, Coulomb found that thin lozenge-shaped bars *directive force* than rectangular needles of the same weight, thickness, a

Influence of Hardening and Tempering.—Coulomb, having magneti to saturation, after hardening it to different degrees, and testing it method of oscillations, obtained the following numbers:—

Temperature of hardening	875°	975°	1075°
Time of 10 oscillations	93″	78″	64″

Steel does not undergo any sensible modification of structure wh temperatures below 870°, and accordingly the magnetic results are t degrees of hardening below this limit; but when hardened at about 11 capable of acquiring double the magnetic force which it retains when ha temperatures: for the time occupied by the ten oscillations being 63″ ins magnetic forces are inversely as the squares of these numbers, that is as

A steel bar hardened at a cherry-red heat, and then magnetised aft tempered at different degrees, gave the following results:

Tempering heat	15°	267°	512°
Time of 10 oscillations . . .	63″	64·5″	70″

Hence it appears that the magnetic force is less in proportion as the ste pered, the coercive force in fact diminishing with the hardness.

Very different results were obtained with thin and very elongated lam By magnetising them at different degrees of hardness, Coulomb found dened at a white heat, they did not retain a higher degree of magne after having been completely tempered. In proportion as the hardness by tempering, the magnetisation became stronger, down to the temperi a dull red heat. On tempering them still more, the directive force w capable of receiving continually diminished. Biot explains this anomal tion of two consecutive poles in very elongated and strongly hardened ne of the needle thus possessing two poles of contrary name, whereby the d greatly lessened. But as the hardness is diminished, the poles neare approach continually nearer to it, and finally disappear altogether.

Compass needles are usually tempered at the blue, that is to say, at In this state, the coercive force, though not at its maximum, is still very steel is less fragile than when more hardened, and less liable to acquire co

Nobili (Bibl. Univ. lvi. 82) has endeavoured to explain the influen on magnetisation by the inequality of density of the different parts of the He found that when a bundle of thin steel wires (about 50) was very st tised, and the wires separated a short time afterwards, each of them ap magnetised in the same direction; but when the bundle was made up ag a few hours afterwards, several of the wires were found to be unmagnet had had their polarity reversed. Similar results had previously bee Coulomb. It appears then that, in a system of parallel rows of magnetised which are most strongly polarised destroy or reverse the polarity of the and determine the polarity of the whole, and if the original polarity of all equal, the magnetic power of the entire system would probably soon be a magnetised bar may be regarded as made up of concentric layers of pola and if the external shell is rendered denser than the interior by harde larger number of magnetic elements are there included within a given ternal shell will receive a higher degree of polarity than the external accordingly will neutralise their action and determine the polarity of the For the same reason soft iron which has been hammered or wire-drawn power of retaining a certain portion of magnetism. According to this cive or retaining power does not depend upon any peculiarity in the pl mical constitution of steel, but is entirely due to the different densities ficial portions of its mass. This is in accordance with the fact that capable of retaining a proportionally greater power than large ones, thei greater in proportion to their volume. It is also supported by the fol ment made by Nobili. Two cylinders were constructed of the same kin of equal length and diameter, but one solid, weighing 28 grms. the weighing 16 grms. They were then hardened to the same degree, and b netised to saturation. When placed at equal distances from a comp solid cylinder deflected it 9½°, the hollow cylinder 19°. The great diffe

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he hollow cylinder, the mass of which was not much more
r, appears to be due to the circumstance that it was hardened
and was therefore covered on both surfaces with the dense
the preceding view, preserves the magnetic power, whereas
is hardened only at its outer surface. On the other hand,
:ted that this mode of explaining the retaining power of steel
nown fact, that iron containing a small quantity of sulphur
gnetism, although perfectly homogeneous, and that very hard
ttracted by the magnet.

power of magnets is diminished by rise of temperature,
y according to the degree of heat applied. The effect of heat
e force; and at a red heat, as first observed by Gilbert, a steel
f its power. When, on the other hand, a magnet is only
suffers only a temporary diminution, the original intensity
This circumstance must be attended to in estimating the
earth's magnetism at different localities, by observation of
etic needle, as, if the temperature is higher at one place than
ist be made for the diminution of magnetic intensity in the

netism is more easily imparted to steel at high temperatures;
powerfully magnetised by placing it while red hot between
strong magnets and cooling it quickly in that position.
ess and then hardened by sudden cooling in the vertical posi-
n imparted to it by the inductive action of the earth.
the decrease of the magnetic force of a bar as its temperature
ed the bar so that its coercive force should not vary during
nagnetised it and heated it to various temperatures, he ob-
s:

.	15°	50°	100°	264°	425°	637°	850°
.	63″	97·5″	104″	147″	215″	290″	very great.

he effect of heat upon a magnet is not instantaneous, but
ie to produce the utmost diminution of power of which it is
plunging a magnet several times into boiling water, and
n minutes, a diminution of the magnetic force took place at
sixth, after which the power remained constant. Kupffer
one half of a magnet is heated, that half becomes weakened,
aches nearer to the opposite end. According to Christie,
inution of the force of a magnet by heat takes place instan-
s in accordance with the accumulation of magnetic power

chanical Actions on the Magnetic Power of Iron.

asion to notice the influence of friction, percussion, and other
rticles of bodies, in diminishing the coercive power of iron
ng the power of permanent magnets, and facilitating the
by induction. Various other mechanical actions which pro-
on in the molecular condition of a mass of iron, likewise
tion in the magnetic power which may be induced in it by
ng its original magnetic power as soon as the disturbing

ay of examining the effect produced by torsion on the mag-
levised by E. Becquerel, which consists in making use of
elix enveloping the magnet, by every increase or diminution
51). For this purpose, a wire of well annealed iron, stretched
ugh a vertical glass tube, round which is coiled a helix in
galvanometer. The wire in this position becomes magnetised
he earth, and it is found that, on twisting it either way, the
ected, in a direction which shows that the magnetic power
by the torsion; and when the wire is untwisted, the needle
tion, indicating that the magnetic polarity of the wire is
nitive state. On allowing the wire to oscillate freely by
the electric circuit a commutator which changes the di-
ugh the galvanometer every time it is reversed in the helix,
nts when the wire passes through the position of equilibrium
continuous current may be obtained.

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Wertheim has made numerous experiments on the relations betw and torsion, by a method similar to that of Becquerel, using however of iron enveloped by two helices, one formed of thick wire to receive th magnetises the bar, the other of a long thin wire to receive the induc convey them to a galvanometer. The helices are placed near the ends occupy but a small portion of its length. Having first shown that always possesses a certain amount of coercive power, and therefore a certain amount of the magnetic polarity once induced in it, Wertheim following results:—1. Torsion and detorsion do not by themselves de netism in iron: for on placing the bar at right angles to the magnet twisting it, no induced current is developed.—2. If the bar is placed meridian, or subjected to the action of a magnet placed on the continu or to the action of the electric current, the magnetising action of either is accelerated both by torsion and by detorsion; but when once equilibrium is established, torsion weakens the total magnetisation restores it to its former amount: hence the maximum of magnetisation the state of *mechanical equilibrium*.—3. If the bar is withdrawn from t magnetising agent, repeated torsion and detorsion quickly destroys the porary magnetisation, but continues to act indefinitely on the permanen which is diminished by torsion and restored by detorsion.—4. When t given condition of magnetic equilibrium, all the effects of torsion are the angles of torsion; but the magnitude of these effects appears to de upon the permanent magnetisation, than on the temporary magnetisati the external cause.—5. The form of the section of the bar does not any influence, but the deflections increase with its area and with the magnetisation.—6. The order of the effects produced is the same for a the only difference being in the absolute intensities of those effects. T requires the greatest number of torsions and detorsions, to bring it to magnetic equilibrium, indicated by the equality of the opposite indu 7. Steel also, the more it is hardened, requires a greater number o detorsions to bring it to a state of magnetic equilibrium; but equilibrium is established, it cannot, according to Wertheim, be mod and detorsion alone, as is the case with iron. Matteucci, on the oth obtained feeble currents in this case, these currents being weaker as the hardened. Hard iron exhibits an anomaly which has not been explaine tion produced in it by torsion being greater immediately after the inte magnetising current than during its passage. In this case, the dimi take place till after some time.

When the bar is in a state of temporary or permanent torsion be tion, similar results are obtained; that is to say, the magnetic maximu not with the initial state of torsion, but with that which exists i mechanical equilibrium; so that the magnetism increases when the b the direction which diminishes the primitive torsion, and diminishes wi torsion is re-established. But if the initial permanent torsion is pro bar is under the action of the magnetising current, a *rotation of th* observed; that is to say, the maximum is displaced, and in the direction the angle of rotation being greater as the iron is harder, and the per greater. This angle is always less than half the temporary torsion wh takes place during the production of a permanent torsion.

For further details on this subject, and on the reciprocal influence of torsion, see Wiedemann (*Galvanismus und Electro-magnetismus*, ii.

Traction and Flection.—According to Matteucci, a sudden elong by tension in a wire of iron or steel, while subjected to the magnetisi electric current, produces an *increase* in the magnetic force, and a sud diminishes it. These results have been confirmed by Wertheim, who that *flection* and *deflection* act in the same manner as torsion and detors effects are due to the displacements of the molecules produced by these whereby they are enabled to arrange themselves, either in the position for magnetisation, or the contrary.

Wertheim finds, in the increase of the magnetic capacity of iron by planation of the well-known fact, that a magnet while loaded becom stronger, but returns to its primitive state as soon as the weight is rem attributes the great irregularities of the compass in large iron ships to flections of the iron which take place during the voyage, these flect changes in the magnetisation of the iron, of which the *compensato* unable to take account. These phenomena are the converse of tho Joule (Phil. Mag. xxx. 76 and 225), who found that an iron bar increases

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circumstances, but contracts if already powerfull/ stretched
vious to magnetisation.

tism compared with Electricity.

netic induction, above described, are analogous in almost
f static electric induction; but there is one essential dif-
there is no such thing as magnetic discharge. In the
we know that, when the opposite polarities of the neigh-
certain degree of intensity, discharge takes place between
ark; and the distribution of the electric forces, after this
same as before, the one body appearing to have lost a
and the other to have gained it (ii. 385). But in magnetic
ind is observed. Whatever may be the power of a magnet,
ece of soft iron may be polarised by contact with it, the iron
magnet; but as soon as the contact is broken, the soft iron
teel magnet is found to have lost nothing, but rather to have
. Neither does hard iron or steel, though it remains mag-
ake any power from the original magnet, its retention of
gous, not to the condition of a body which has been electri-
non-conducting body like sealing-wax, which has been elec-
and then removed from the neighbourhood of the inducing body.
netism are not then precisely analogous to those of static
; the exact parallelism which exists between the two up to a
ready explained under ELECTRICITY (ii. 447), the laws of
pulsion are exactly similar to those of the mutual action of
lices of copper wire, through which electric currents are
one another exactly like magnets, and, accordingly, all the
traction and repulsion may be accounted for, if we assume
n aggregate of particles having electric currents constantly
one direction. This theory has been sufficiently developed
nd we need not dwell upon it further.

teel is rendered magnetic by the action of an electric current
gles to its length, we must suppose, if this theory be true,
the power of inducing in magnetic bodies a system of electric
ion as itself; moreover, that these currents, once established,
as long as the original current continues to act, and, in the
has ceased. Now, this is not what is observed to take place
rrents on conducting bodies in general. We know that when
a closed circuit is placed near another wire conveying an
, at the instant when it begins to flow, induces, in the first
direction to itself, this current, however, being merely in-
ed current being perceptible so long as the inducing current
iform strength; and, finally, that when the original current
it is broken), another momentary current passes through the
direction as the inducing current. These effects of electro-
idently totally different from those which must be supposed
according to Ampère's theory; and we must, therefore, sup-
have a peculiar molecular constitution, which enables an
ar them to excite continuous currents round their particles in
wn; or rather, perhaps, that these currents pre-exist in all
re the development of magnetic polarity, but are disposed
hat they neutralise one another; and that magnetisation,
nt, or by another magnet, is the process by which these mole-
move in one direction (ii. 448).

molecules of magnetic bodies, such as iron and steel, are en-
ed currents of electricity, which, before the development of
e indiscriminately in all planes, but, in a magnetised bar,
that, on the whole, the prevailing direction of rotation is in
of the hands of a watch conceived as situated at the centre
wards the south pole and its back towards the north pole,
ar to the line joining the two poles: this hypothesis accounts
facts connected with magnetisation, and receives from some
nation. According to this view, magnetisation consists in
piece of iron such an arrangement that the prevailing direc-
nts shall be that indicated above. Coercive force is, on the
the motion of the particles, which requires to be overcome
etisation or demagnetisation; and the saturated state of a

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magnet is when the greatest possible number of molecular currents circulate
same direction, with their axes parallel to that of the magnet.

That magnetisation is really attended by molecular motion is proved by the er
of musical sounds by a piece of soft iron which is suddenly magnetised or der
tised, when it is so supported that the greater part of its mass is free to vibrate.
magnetic effects developed by torsion likewise show the intimate connection b
molecular motion and magnetisation. This view also enables us to see why the c
force of steel is increased by hardening; for the hardness of steel is nothing mo
the result of the great resistance which its molecules oppose to mutual motion
difference between the molecules of soft iron and those of steel with respect t
netisation, may be regarded as analogous to that presented by a very finely
magnetic needle and one that is coarsely hung, when a magnet is brought near
The finely hung needle is immediately and completely turned from its normal p
on the approach of the magnet, and at once returns to it when the magnet is rer
the coarsely suspended needle, however, is at first much less affected by the m
and does not turn to the full extent until the friction of its point of support is ov
by a gentle tap or shake, and, similarly, when the disturbing magnet is taken away,
not return completely to its first position without the same aid. This comparisc
serve to explain the influence of a blow or vibration in facilitating the magnetisa
an unmagnetised steel bar, and in weakening the force of a saturated steel mag

Universality of Magnetic Action—Diamagnetism.

Magnetism was for a long time regarded as peculiar to a small number of bodies, n
iron, nickel, cobalt, and certain of their compounds; but later researches have shown
bodies are more or less susceptible of magnetic influence, though they are not all a
in the same way. The question of the universality of magnetism was raised as e
the beginning of the eighteenth century. Muschenbroek and Nollet found
large number of bodies in the state of powder, the ashes of plants, and small fra
of organic substances, were attracted by the magnet; but they attributed the re
the presence of small quantities of iron in the substances examined. The subje
also investigated by Lehmann and Cavallo; and Brugmanns, in 1778, ob
that bismuth is *repelled* by the poles of powerful magnets,—a remarkable dis
which did not receive at the time the attention it deserved. Coulomb, in
found that fine needles of gold, silver, and other metals, also of glass, and of variou
table and animal substances, suspended by a thread of unspun silk between the o
poles of two powerful magnets, oscillated till they came to rest in a line betwe
poles; but he also showed that a very minute quantity of iron, not exceeding
intimately mixed with a needle of wax, was sufficient to produce this effect: he
considered it uncertain whether the effects observed were due to the action of th
nets on the various substances themselves, or on minute quantities of iron conta
them. After the discovery of electro-magnetism, Becquerel observed that
shellac, wood, and other substances, suspended by threads of unspun silk with
coil of a galvanometer, placed themselves with their axes *parallel* to the plane
coil, instead of at right angles to it, as an iron needle would: this effect was ex
in a remarkable manner by a paper tube filled with ferric oxide. Lebail
1828, found that a delicately suspended magnetic needle was repelled by bismu
antimony, thus confirming the important observation previously made by Brug
The same kind of repulsive action was subsequently observed by Saigey in
other substances.

But these facts, however important they may now appear, excited but little att
at the time of their discovery, inasmuch as they could not be referred to any
law; and the question of the universality of magnetism remained undecided
Faraday, in 1845, discovered that most transparent substances, when subjected
influence of powerful magnets, acquire the power of circular polarisation (p. 676
regarding this effect as resulting from the action of the magnet on the molec
the transparent body, he was led to undertake a series of researches which resu
the grand discovery, that all bodies whatever are subject to magnetic influenc
are not all affected by it in the same way, being divided, with respect to their ma
susceptibilities, into two great classes—the *Magnetic* and the *Diamagnetic*.
former class includes those bodies which exhibit the well-known phenomena o
nary magnetic attraction and repulsion—being *attracted*, when in their natural
by either pole of a magnet, and, when shaped into bars or rods, and suspended
two opposite magnetic poles, pointing *axially*—that is to say, in a straight line b
them. The bodies belonging to this class are mostly metallic (including oxides and
viz. iron, nickel, cobalt, manganese, chromium, cerium, titanium, palladium, pla
osmium. The magnetic properties of iron, nickel, and cobalt have long been

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series, magnetic susceptibility can only be detected by the
ver. Manganese, chromium, cerium, titanium, and osmium
he magnetic class, because certain of their compounds exhibit
ions.

etic class includes all liquids and solids, both organic and
long to the *magnetic* class. The law which governs the
e bodies is as follows:—*A particle of a diamagnetic body*
od of either pole of a magnet is repelled *by that pole.*
gnetic substance suspended by its centre midway between
nt *equatorially*, that is to say, at right angles to the straight
-that being the position in which every part of it is at the
om each of the poles; and if its centre be placed on either
whole bar will recede from that line, placing itself at the
globe or cube does not *point*, but exhibits the simple phe-
two small balls of any diamagnetic substance be suspended
poles, they will be driven towards one another, as if they
traction. The position which a bar of any substance takes
tally between two magnetic poles furnishes the best means
belongs to the magnetic or the diamagnetic class: if it be
f axially; if diamagnetic, equatorially.

annot be perceptibly developed without the use of exceed-
lectro-magnets answer the purpose best, but large perma-
used. The great power required to develope this mode of
ng been previously overlooked by most observers.

the most powerfully diamagnetic of all substances; then
timony, then heavy glass (silico-borate of lead). Among the
gnetic energy appears to be as follows: bismuth, antimony,
mercury, lead, silver, copper, gold, arsenic, uranium, rho-
(Faraday, *Experimental Researches in Electricity*, series
46, 21.)

magnetic, being nearly equal in that respect to bismuth.

ibit decided magnetic and diamagnetic relations. In his
subject, Faraday was led to the conclusion that gaseous
nagnetic action, forming the zero, or middle point, between
and diamagnetic bodies. Bancalari has, however, since
sses diamagnetic properties; and Zantedeschi has shown
kewise exhibit diamagnetic relations. The researches of
ave been confirmed and extended by Faraday: the follow-
s.

de by which a stream of any gas could be delivered in a
wards or downwards, near the middle point of the axial
magnetic poles of opposite names, but at a short distance
y this arrangement it was found that the following gases
e magnetic axis and passed off in the equatorial direction;
d diamagnetic relations with regard to atmospheric air—
c anhydride, carbonic oxide, coal-gas, olefiant gas, sulphur-
c acid, hydriodic acid, fluoride of silicium, ammonia, chlo-
vapours of bromine and iodine. Nitric oxide and pernitric
magnetic in air. Oxygen was strongly magnetic—that is
ls the axis, and then along it in opposite directions towards
it accumulated.

s evidently differed from each other in diamagnetic energy;
by the means above described to form anything like a pre-
ive powers. To determine this point, the magnetic poles
mosphere of one gas, while the other gas was directed in a
ards or downwards, near the axial line as before. By this
(1) *In carbonic anhydride*, air and oxygen passed axially;
, olefiant gas, hydrochloric acid, and ammonia, equatorially:
de and nitrous oxide, but the action was feeble. (2) *In coal-*
ic, though but slightly; oxygen was strongly magnetic:
gnetic; olefiant gas, carbonic oxide, and carbonic anhydride,
gen gas, air, when free from smoke, passed axially; but
was either indifferent or passed equatorially. Hydrogen
em to be not far removed from one another in the scale.
etic; nitric oxide also magnetic, but in a less degree. Ni-
gnetic; nitrous oxide, carbonic oxide, carbonic anhydride,

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and olefiant gas were also diamagnetic; hydrochloric acid and c
Oxygen appears to be the most magnetic of all gases.

When a spiral of platinum wire was placed just below the middl
line and ignited by a voltaic current, the stream of hot air which
axial line was deflected at right angles to the axis, and passed o
direction. The same effect was obtained in oxygen, carbonic anhy
Hence it appears that a heated gas is diamagnetic to the same wh
of cold air directed downwards near the axial line, was drawn tow

The flame of a wax taper or of burning ether also takes an equat
placed in or near the middle of the axial line. When placed a l
the axis, it is directed away from that line, just as if a gentle wind
it in that direction. When made to rise exactly in the axial line, i
two long tongues, directed at right angles to the axis. This effect i
ing with the large flame produced by setting fire to a ball of cott
These effects are evidently analogous to those just described with
are doubtless partly due to the solid carbonaceous particles in th
diamagnetic. In corroboration of this supposition, it is found
flames are the most strongly diamagnetic. (Faraday, Phil. Mag.
also Zantedeschi, xxxi. 421.)

Specific Magnetism. This term was introduced by E. Bec
the action exerted by a magnet on the unit of volume of a body pl
distance, as compared with that which is exerted on a certain subs
standard of comparison. Another mode of estimation is to comp
duced on a small magnetic needle, by a cube, equal to the unit of vo
unit of distance from the needle. The measurements are made e
balance, or by determining the weight required to keep the body i
of equilibrium while under the influence of the magnet.

By these methods, Plücker, representing the specific magneti
100,000, has found for native magnetic oxide the number 40,227, f
533, for brown hæmatite 71, which is the lowest number found f
pounds of iron, solid or liquid.

The following are the results obtained by Plücker for certain *dia*
at ordinary temperatures, and for equal weights referred to water a

Specific Diamagnetic Powers. (Plücker.)

Water	100	1	Flowers of sulphur
Phosphorus	100	1	Common salt
Sulphide of carbon	102	1	Nitric acid
Hydrochloric acid	102	1	Nitrate of bismuth
Ether	127	⅔	Sulphuric acid
Oil of turpentine	123	⅔	Mercury

This table shows that the diamagnetic powers of different groups
be approximately expressed by simple numbers; but it is doubtful
is accidental, or expresses an actual law.

The following table contains some of the results obtained by E
magnetic power of water being taken as unity, and the results referre
Diamagnetic substances are denoted by the *minus* sign.

Specific Magnetic Powers. (E. Becquerel.)

Solids.	Specific magnetism in air.	Liquids.	
Water	−1·00	Water	1
Zinc	−0·25	Alcohol	0
White wax	−0·57	Ammonia	0
Melted sulphur	−1·14	Common salt	1
Copper (electrotype)	−1·41	Chloride of magnesium	1
Copper, pure	−1·68	Sulphide of carbon	1
Lead, commercial	−1·53	Sulphate of copper	1
Phosphorus	−1·64	„ of nickel	1
Selenium	−1·65	Ferrous sulphate	1
Silver, pure	−2·32	„ „	1
Gold (nugget)	−2·41	„ chloride	1
Gold, pure	−3·47	„ „	1
Bismuth	−21·76	„ „ (concentrated)	1
„	−22·67		

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powers of iron with water, and thence with other bodies,—
t, on account of the very great disproportion existing
l made use of the concentrated solution of ferrous chloride,
comparison. This solution, which has a specific magnetic
water being −10, was introduced into a tube of thin glass,
ed between the contrary poles of two bar magnets, and its
with that of a bar of wax of the same length mixed with
n filings. The numbers of oscillations made by such bars
ndent of their bulk, and proportional to the quantity of
In this manner it was found that ferrous chloride expe-
he same amount of action as an inert substance containing
ic centimetre. Now, the magnetic power of water, com-
being $\frac{-10}{+658{\cdot}13} = -0{\cdot}0152$, will also be equal to that of an
$0{\cdot}0152 \times 0{\cdot}2 = 0{\cdot}003$ milligr. of iron per cubic centimetre,
ce, as a cubic centimetre of iron weighs 7·758 grms., the
rous chloride, and water are, for *equal volumes*, as the num-
0·4; and for *equal weights*, as +1,000,000 : +140 : −3.
ed the magnetic powers of a considerable number of sub-
orsion. The next table contains some of his results for
l referred to water as unity. They were all obtained at
(60° F.), and for gases under the pressure of 0·76 metre.

fic Magnetic Powers. (Faraday.)

Substances.	Magnetic powers.	Substances.	Magnetic powers.
Cyanogen . .	−0·009	Ammonia (liquid)	−1·010
Glass . .	−0·188	Sulphide of carbon .	−1·031
Zinc, pure .	−0·772	Nitrate of potassium (sat.)	−1·036
Ether . .	−8·797	Sulphuric acid .	−1·081
Alcohol (abs.) .	−0·815	Sulphur . .	−1·221
Oil of lemons .	−0·828	Chloride of arsenic .	−1·260
Camphor . .	−0·855	Borate of lead (melted)	−1·413
Camphine . .	−0·859	Bismuth . .	−20·369
Linseed oil .	−0·886		
Olive oil . .	−0·886		
Wax . . .	−0·887		
Nitric acid .	−0·911		

ific magnetic powers of different elementary bodies shows
most magnetic are those which have the smallest atomic
ose atoms are the closest together; and that diamagnetic
e those whose atoms have the largest spaces between them.
agnetic of all bodies, has also a high atomic volume (21·2);
balt have very low atomic volumes, viz. about 3·5. But
and zinc, which have also small atomic volumes, viz. 3·6
htly diamagnetic; and sodium and potassium, whose atomic
ose of any other metals (sodium 23·7, potassium 45·6),
htly magnetic. The relative distances between the atoms
nd perhaps not the principal, cause which determines the
and diamagnetic bodies.
yet been discovered between the magnetic or diamagnetic
l those of their elements. It is known, however, that the
the most part magnetic; but exceptions occur even among
ferricyanide of potassium, for example, being diamagnetic.
toms are, therefore, dependent to a certain extent on their

agnetic powers of mixtures are, according to Matteucci,
? the mean] of those of their components.
ygen and Air.—Matteucci has compared the magnetic
f iron by the following method, which serves also to show, in
gen is magnetic:—A large bubble of oxygen is introduced
ol, and the tube is placed transversely between the hemi-
of a very strong electro-magnet. If the bubble is placed
e, it elongates towards this line; and if its centre is over the

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polar line, it shortens. If the alcohol is saturated with protochl
bubble in the latter position splits into two, which move away from
ascertaining by trial the proportion of ferrous chloride, for which the b
no perceptible change of form, a solution will be obtained, having t
power as oxygen gas. By this method Matteucci found that oxyg
magnetic power as an alcoholic solution of ferrous chloride conta
grammes of iron in a cubic centimetre.

E. Becquerel has made numerous experiments for the purpose
magnetic power of oxygen as compared with water, and thence with
tube of glass filled with wax was suspended from a torsion apparatu
produced upon it by an electro-magnet in a vacuum, in oxygen and
pared. These actions, at the temperature of 12°, were, *in oxygen* u
0·76 met., $V_o = -0·2675$; in a vacuum, $V_v = -0·1145$; and
$+0·7033$. Hence $V_o - V_v = +0·1530$: $V_w - V_v = -$
magnetism of *oxygen*, compared with water *in vacuo*, is 0·1530 : 0
Hence, for equal volumes, the magnetic power of oxygen is nearly $\frac{1}{2}$
but of contrary sign. For *air* the same method gives the number 0
the magnetic power of oxygen multiplied by 0·21 is 0·392, it follows
power of the air is due to the oxygen contained in it. These resu
same as those obtained by Faraday (p. 773) and Matteucci; and Bec
confirmed them by Plücker's method. Lastly, he has shown that th
of oxygen is proportional to its pressure—a result probably true also

Taking the magnetic power of iron as the standard, and calling
find that, for *equal weights*, the magnetic power of oxygen is 377, a
Oxygen, *weight for weight*, has three times the magnetic power of
which is the most magnetic of all liquids. Hence a cubic metre of
act on a magnetic needle with the force of 54 centigrammes of iron,
of air with the force of 11 centigrammes of iron. The whole atmosphe
equal in magnetic power to a shell of iron covering the whole earth
0·1 millimetre. It is easy to conceive that such a magnetic envelo
constant agitation, is capable of disturbing the magnetic needle; a
power varies with its temperature (see below), the heating which
different hours of the day may contribute to produce the diurnal varia

Influence of Temperature on Magnetism and Diamagnetism.—The
the magnetic power of iron and steel has already been mentioned
formerly supposed that iron at a white heat becomes totally unsuscep
influence. Faraday has, however, shown that, though the susceptib
bodies properly so called is rapidly diminished by heat, it is
destroyed, but is still perceptible at the highest temperatures, provi
magnets of great power are employed to develope it. These result
firmed by Plücker, who has shown that the specific diamagnetism
solids and liquids diminish, for the most part, as their temperature i
there are some exceptions to the rule. Mercury, for example, exhib
diamagnetic power at 300°; neither do sulphur and stearin, even w
their melting points. Brunner has shown that water in the state of
has the same specific magnetism as in the liquid state.

According to Matteucci (Bibl. Univ. de Génève [Arch. des Sc
magnetism of iron increases up to a certain temperature, then decrea
diamagnetic power of bismuth diminishes between 0° and 212° C.—n
to the increase of temperature, and vanishes altogether at the melt
metallic bodies, on the contrary, such as sulphur and phosphorus,
diminution of diamagnetic power in consequence of change of state.

A globule of iron melted in a lime-spoon by the oxy-hydrogen
attracted by the magnet; but to exhibit the attraction, a very large el
required, charged with 30 Grove's cells. Matteucci estimates the m
melted iron at only 0·000015 of its power at common temperatures
surprising that iron at a white heat should have been found insensibl
power of ordinary magnets. Copper, standard gold, zinc, porcelain,
of charcoal, which according to Matteucci are magnetic at common tem
diamagnetic when heated. Platinum remains magnetic in the state
appearing scarcely to have suffered any diminution.

Heat appears also to diminish the magnetic power of gases: thus F
heated air is repelled by the magnet when surrounded by cold air (p. 77
however, concludes from his experiments on oxygen, that heat does
diminishing the magnetic power of gases, the diminution observed b
change of density.

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and Crystalline Structure on Magnetism and Diamagnetism.

ne position assumed by a bar of bismuth under the influence
d in a remarkable manner by its crystalline structure; and
f the metal is suspended between the poles of an electro-
rpendicular to the principal cleavage-plane of the crystal
ne-crystallic axis), tends to place itself axially between the
the field, tangentially to the magnetic curve passing through
is situated. Plücker also remarked that a plate of tour-
is, and suspended between the poles of an electro-magnet
aces itself with the axis in the equatorial position, although
consequence of the iron which it contains, and if suspended
racted by either pole of the magnet. Hence he concluded
the magnetic poles, and that the repulsion thus exerted is
raction due to the magnetic properties of the mass. Calc-
h is diamagnetic, places itself with its principal crystal-
between the magnetic poles: similar results are obtained
se, which are magnetic.

been reduced to a general law by the researches of Tyndall
n. Phys. [3] xxxv. 375; xxxvii. 76), who have shown that
dy are more closely packed in one direction than in others,
nstances being the same—is the one on which the forces
exerted with the greatest energy, and consequently this
elf axially or equatorially between the poles of a magnet
netic or diamagnetic. Thus a cylinder of carbonate of iron
, places itself axially, if of uniform density in all directions;
y pressed between boards into a thin cake, a bar or needle
itself equatorially between the poles, even if its length be
breadth. Conversely, a bar formed of a paste of bismuth
ces itself equatorially if of uniform density, will assume
ste be compressed transversely to the length of the bar.

rystals of bismuth and other substances are of the same
r structure of crystals is not the same in all directions, is
lations, their rates of expansion, and their heat-conducting
which they place themselves under the influence of a magnet
ive densities in different directions, in the same manner as
bove mentioned.

rection of the axis of a crystal that ultimately determines
es under the influence of a magnet, so much as that of the
anes taking the axial direction when the crystal is magnetic,
amagnetic.

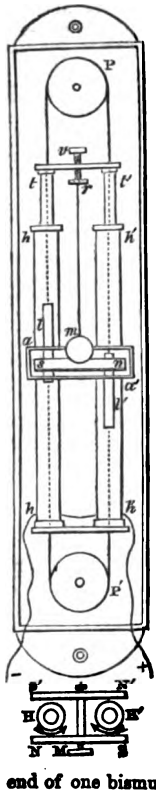
med of the same dimensions, one from a crystal of beryl,
th of which are magnetic, the former will place itself with
ly between the magnetic poles, the latter axially, because
s are perpendicular to the axis, whereas in scapolite they
ely, a cube of nitre, which is diamagnetic, places itself with
l, whereas a cube of topaz, also diamagnetic, takes up the
the cleavage-planes of nitre are parallel, and those of topaz
ncipal axis of the crystal. In all cases, the cleavage-planes
equatorially, according as the crystal is magnetic or dia-
which this result is produced will be easily understood if
may be regarded as an aggregate of very thin plates laid
not in absolute contact. It is easy, indeed, to imitate the
hus, if a number of strips of emery-paper, an inch long and
be gummed together one upon the other, so as to form a
ll place itself axially between the poles of a magnet (the
fact, it represents a magnetic crystal having its cleavage
But if another bar be formed, also an inch long, of square
arter of an inch broad, having their surfaces transverse to
self equatorially, because, in that position, the layers of
e up the axial position. If the paper be covered with a
instead of emery, the effects will be exactly opposite.—
De la Rive (i. 516—529).

7. Soon after the discovery of diamagnetism, the question
gnetic bodies possess opposite poles analogous to those of
from his earlier experiments, concluded that such was not
t of a diamagnetic body was equally repelled by either
other hand, Reich (Ann. Ch. Phys. [3] xxxvi. 127) found

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that a very delicately suspended ball of bismuth, though repelled by horse shoe magnet, when presented to them separately, remained at pended at equal distances from the two: hence he concluded that the of the two magnetic poles is due, not to the sum, b ence of their action, just as would be the case wit actions exerted by the two poles on a ball of iro first effect of the magnet on the bismuth is to deve tain polarity, whence results the repulsion. The qu wise examined by Weber and Poggendorff, Plücker and Matteucci, but without decisive results, and the the existence of diamagnetic polarity remained dou taken up by Tyndall (Phil. Trans., 1855 and 1856 of an apparatus suggested by Weber, has completely existence of polarity in diamagnetic bodies.

Fig. 727.



This apparatus, represented in *fig.* 727, consists of cal helices, *h h*, *h'h'*, having an internal diameter of and coiled round copper tubes, which project abov these two helices convey the same electric current, directions. They are fixed to a stout board susp wall, and within them are suspended two small diam attached to an endless cord passing round the pu astatic needle, *s n*, represented in projection at N pended on a level with the middle of the helices *h*, attached to the centre of a torsion-circle, *r*. This of turning independently of the screw *v*, the nut bedded in a copper cross-piece fixed to the extremit tubes *t*, *t'*. The magnets NS, N'S' are enclosed in a c diminish the amplitude of the oscillations; they are rod, on which they can be made to approach one ano

The deflections of the astatic needle are observed l mirror *m*, M, and measured by the reflection of a placed at a distance, as in Gauss's magnetometers. a voltaic current from one or two Grove's cells t coils in opposite directions, the bismuth bars with diamagnetised; and by carefully raising or lowering NS, S'N', a position may be found in which the mag different to the action of the current. If, whilst t thus arranged, the wheel P be turned to the right, t will be brought into the position represented in th astatic needle will be deflected. This effect is clear velopment of polarity in the bismuth bars: for, in the opposite direction of the currents on the two h end of one bismuth bar will, if polar, be in the same condition as the other, and each will therefore attract one particular end, say the north composing the astatic combination, and repel the south end: both ba to deflect both magnets in the same direction; on turning the wheel as to bring the bismuth bars into the opposite position, the needles deflected in the contrary direction.

These effects are most marked with bodies like bismuth and antim the greatest diamagnetic energy; but they are also distinctly shown, ducting bodies—such as heavy glass, phosphorus, sulphur, sulphide of

If the deviation produced by solid bismuth be represented by 75 scale employed, the following table will represent the action, found by other bodies enumerated in it:

Bismuth, solid . . .	75	Heavy glass . .	
„ powdered . .	37	Phosphorus . .	
Antimony	13·5	Distilled water .	
Sulphide of carbon . .	5·5	Calcspar . .	
White marble . . .	5	Nitre . . .	

When *magnetic* substances, such as iron in bars or in filings, sulphs chloride of iron, slate, solutions of salts of iron, nickel, or cobalt, are s dismagnetic bars, the astatic needles are deflected in the contrary di which, under the same circumstances, they would be deflected by dian

Theory of Diamagnetism. The phenomena of diamagnetism the inquiry, whether the repulsion exerted by a magnetic pole on di

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f magnetism, as exerted upon iron and other bodies of the
on the other hand, the magnetic and diamagnetic condi-
lative, so that all bodies are magnetic in different degrees,
f a diamagnetic body, such as bismuth, is merely the result
magnet less than the particles of the surrounding medium,
n the earth, because its weight is less than that of an equal
It is easy to show that the same body may appear mag-
ng to the medium in which it is placed. Protosulphate
tance, and water is diamagnetic: hence it is possible, by
aqueous solution of this salt, to make it either magnetic,
when suspended in air. Again, a tube containing a solution
pended horizontally within a jar, also filled with a solution
between the poles of two powerful electro-magnets, will
rially, according as the solution contained in it is stronger
e jar. In the same manner, then, we may conceive that
rially between two magnetic poles, because it is less mag-
air. But the diamagnetism of bismuth and other bodies
lf in a vacuum as well as in air: hence, if diamagnetism
distinct force, we must suppose that the *ether* is also
e magnetic scale the place intermediate between magnetic

n a medium of greater magnetic susceptibility than itself,
pole in its neighbourhood, in consequence of the greater
es of the medium are impelled towards the magnet, is so
echanical laws, that we can scarcely avoid attributing the
odies to the cause just mentioned, at least, when the body
er magnetic gas. There is, however, some difficulty in
exhibited by compressed and crystallised bodies (p. 774)
ll some time ago (Phil. Mag. [4] ix. 205) objected
f diamagnetism as well as that of magnetism is in-
ereas, if the repulsion of a diamagnetic body were merely
ttraction exerted upon the particles of the surrounding
est in that direction in which the body is most compressed,
must increase the total amount of attraction exerted on
that direction, but cannot in any way affect that which is
medium. Williamson (Proc. Roy. Soc. vii. 306) has,
in considering this question, it is necessary also to take
rted on the magnetic medium (or *ether*) interposed between
c or diamagnetic body. When a cube of carbonate of iron
le particles being more magnetic than the medium which
n which the body is attracted is increased proportionally
es more magnetic by compression, we must conclude that
m from its interstices is more than supplied by the mag-
ts place. Carbonate of calcium, on the other hand, is less
of medium which its particles displace; and when these
together by pressure, the mass becomes more diamagnetic,
f the magnetic medium is thus replaced by the less mag-
ies, so long as they retain their original crystalline forms,
n in which the function of the ponderable particles predo-
that of the medium; so that in the iron-salt it is the
n-salt the feeblest magnetic direction of the crystal. On
roc. Roy. Soc. vii. 448) suggests that, in estimating the
et on the particles of a body and the magnetic medium
unt must be taken of the relative intensities of the action
different directions: and he endeavours to show, by a process
must refer to the paper above quoted, that, in two out of
), when the attraction of the magnet on the interposed
tions with regard to the line of compression, and (2) when
ction, the repulsion produced on a body whose specific
ess than that of the medium, will be a minimum in that
that in these two cases, the objection raised by Tyndall
agnetism under consideration is valid: but that, thirdly,
ble case in which the action of the magnet on the
test in the direction at right angles to that of strongest
le particles, the latter may be so far diminished, that
rongly repelled by a magnetic pole in the direction of
herefore, this third case be also taken into account, Tyn-

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dall's objection to the theory of a magnetic medium cannot be re
decisive.

On the whole, then, the phenomena exhibited by compressed and
do not quite decide the question whether diamagnetic repulsion is n
phenomenon, or whether it is due to the action of a specific force.
differential, can, as already observed, scarcely be doubted; but, on t
existence of diamagnetic polarity shows decidedly that the effect is
this cause: for if it were, every part of a diamagnetic body wou
either pole of a magnet.

It becomes necessary, therefore, to seek some further explanation o
diamagnetism; and the following theory has been proposed by Webe
We must suppose, in the first place, that each molecule of a body
polarity, by virtue of which, negative electricity tends to accumulate
c, of its surface (*fig.* 728), and positive electricity at the opposite
molecule is isolated and a good conductor, the two electricities wil
its surface, forming currents contrary to those which are continually b

Fig. 728.

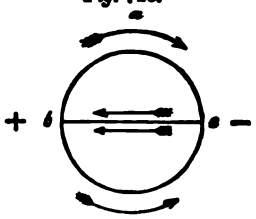
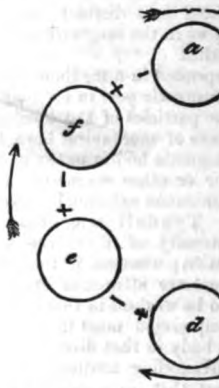


Fig. 7



interior to re-establish the polar tension; and the actions which these c
to produce on any external point, destroy one another. If now th
posed to make one of a group, all the atoms of this group will act
as to bring their contrary poles towards one another, as in *fig.* 729
electricities, instead of recombining on the surface of each molecul
molecular discharges, and, consequently, a current in the direction of t
These currents, existing in all the molecular groups, are in fact
assumed to exist in Ampère's theory (p. 769): in unmagnetised ir
directions, and the effect of magnetisation is to reduce them to p
these currents cannot pass between the molecules composing the
molecules are sufficiently close together; and, accordingly, it is fo
bodies are, generally speaking, those whose atoms are most closel
words, those which have the smallest atomic volumes (p. 773). Mo
increases the distance between the atoms, diminishes the magnetic po
may even destroy it altogether. Diamagnetic bodies, on the contrary
speaking, a large atomic volume,—that is to say, their atoms being
these atoms cannot discharge their opposite electricities one to anot
state of the isolated atom (*fig.* 728). If, however, these independen
are brought near an electric current, or the system of currents constit
atoms are brought, by the polarised molecules of the current, into such
contrary poles of the two systems are brought face to face, as in the fo
currents (*fig.* 447, vol. ii. p. 454). Consequently, these atoms will p
their own group, in the same manner as those in *fig.* 729; and if
ciently powerful, the polarity of the atoms of the molecular group w
their mutual influence, to such an extent, that discharges will take p
producing a current in the opposite direction to that of the magnet,
which the body will be repelled from the magnet. According to th
chief difference between magnetic and diamagnetic bodies consists in
former the currents pre-exist round the molecular groups, and me
brought to parallelism by magnetisation; whereas in the latter, the

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ıence of powerful currents, capable of bringing the atoms
ınt.
erable difficulties in the reception of this theory. In the
owers of bodies are by no means proportional to their
ı and sodium, which have much greater atomic volumes
gnetic; whereas zinc and copper, whose atomic volumes are
gnetic. With regard to these two latter metals, De la Rive
good conductors, and, therefore, that the recomposition of
y take place along the surface of each, in spite of their
rt of this explanation he remarks, that on combining copper
ıich diminish its conductivity, it becomes magnetic. But
not account for the magnetism of potassium and sodium,
conductivity between iron and copper. Moreover, it is
g to this theory, the diamagnetism of a body should be
n the whole, it must be admitted that we are still very far
diamagnetism.

RESTRIAL. The magnetic action of the earth has been
in the preceding article: we shall here examine it more
edle suspended by its centre of gravity in such a manner
ll directions, and placed beyond the influence of other
, places itself: 1. At a particular angle with the geo-
ce: this is called the declination.—2. At a particular
he inclination or dip of the needle.

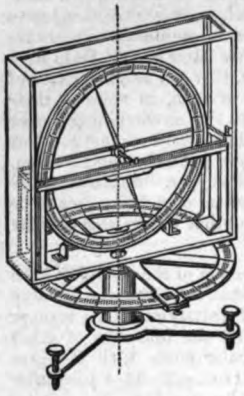
lled the *Variation of the Compass*.—The angle which the
he north and south line, or with the geographical meridian,
ed with a needle whose movements are restricted to a
orting it on a steel point by an agate cap (*fig.* 718), or on a
spended by a thread of unspun silk. When a needle thus
ent parts of the earth's surface, its direction is continually
the world, it points exactly north and south; in all others,
more or less inclined to the geographical meridian of the
ssing through its position of equilibrium is called the
e place.
lirection and in amount both with place and with time.
reference to the position of the north pole of the needle.
declination at London is at present to the west, we mean
edle points west of the geographical north.
urface at which the needle points due north and south are
lled *lines of no declination*. One of these lines, whose
uch from that of a great circle of the globe, may be traced
west of Hudson's Bay, across Canada, into the Atlantic
ast point of South America, near Cape St. Roche, whence
lantic Ocean, and meets the meridian of London near the
de. Another line of no declination passes across the
20° east longitude, traverses the west of Australia in a
ıen passes westwards, forming a large loop enclosing the
elago and the two peninsulas of India, whence it passes
f Japan, and enters Siberia, where it has not been further
ıich is perhaps a continuation of that which traverses the
wards across the White Sea. There are, therefore, two
lination, which probably join one another in the polar
e curve passing round the globe.
e on the west and the Asiatic lines on the east—that is to
the Atlantic Ocean and the Old World—the declination
of the earth's surface it is to the east; and it diminishes
ı these lines. In London, at the present time (1864), the

Suppose a bar of unmagnetised steel to be suspended at its
ıd of unspun silk: it will come to rest in the horizontal
tised, it will not only place itself in the magnetic meridian,
position, the north pole in these latitudes pointing down-
inclination or dip of the needle is best observed by means
y its centre of gravity on a horizontal axis (*fig.* 730), so
ined to a vertical plane. A *dipping-needle* thus mounted
The horizontal circle serves to place the plane of the
gnetic meridian, and the vertical circle to measure the dip.

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As the needle always tends to place itself in the magnetic meridian, it is c
if the vertical plane to which its movements are confined is placed at right
the magnetic meridian, the needle will stand
this being the only position in which it can pl
in the magnetic meridian. If this position be de
and marked on the horizontal circle, the verti
may be placed in the magnetic meridian by r
round 90° therefrom. The angle of inclinat
then be directly observed.

Fig. 730.



The dip, like the declination, is of different a
different localities. There are two points, one
hemisphere, at which the dipping-needle stand
vertical; these are called the magnetic pol
earth; and about midway between them is a li
the magnetic equator, or line of no dip,
it stands horizontally. The magnetic equator i
what sinuous line, not differing much from
circle inclined to the geographical equator at
of 12°, and cutting it in two points near the l
10° E. and 170° W., reckoned from the meridian
At all points between this line and the north
pole, the north pole of the needle is directed do
the contrary being the case in the other magne
sphere. The dip goes on increasing from the
equator towards each pole: in London at the present time it is 68° 15′, r
from the horizontal plane.

On comparing the positions assumed by the needle at different parts of th
surface, it is easily seen that they may be accounted for by regarding the earth
magnet, having its poles at the points where the dipping needle stands vertic
its median line coinciding with the magnetic equator. The northern t
magnetic pole, which corresponds with the south pole of an ordinary magnet, is
on the continent of North America, to the north-west of **Hudson's Bay**, and,
to the observations of Capt. J. C. Ross, made in 1830, in latitude 70° 5′ 17
longitude 96° 43′ W. from Greenwich (*Arago's Meteorological Essays, trans
Sabine*, p. 366). The position of the southern magnetic pole has been appro
fixed by the observations of the same navigator, in latitude 73° S. and longitu
The line of no declination passes through these two points, and the lines of eq
nation converge towards them. From observations made at different points in
and the south of Scotland, between March 1858, and October 1860, Sabine
68° 59′·2 as the dip at the mean epoch, 1st January, 1860, at a point whose
and longitude were the means of those of the stations included in the survey
latitude 52° 20′, longitude 1° 41′ W. from Greenwich. The minimum dip was
at St. Leonard's (latitude 50° 51′, longitude 0° 33′ E.), where it was 67° 44
the maximum 71° 29′·5, at Jordan Hill, near Glasgow (latitude 55° 52′,
4° 19′ W.), the direction of the *isoclinal lines*, or lines of equal dip, be
N. 71° 22′ E. to S. 71° 22′ W. (Rep. Brit. Assoc., 1861, p. 250).

That the earth really acts like a magnet, is further shown by the magneti
masses of iron placed in or near the line of the dip. In our latitude, where
of dip does not differ greatly from the vertical, bars of iron standing constant
vertical directions, such as railings, lightning-conductors, &c., become ma
with their north poles downwards, just as they would be if placed above t
pole of a steel magnet.

The magnetisation of the masses of iron in a ship by the earth's action,
considerable deviation of the compass-needle from its normal position; an
direction of the magnetisation thus induced is constantly changing as the shi
its latitude, it is evident that serious irregularities in the indications of the
may thence result: in short, there are several instances of shipwreck on reco
have been clearly traced to this cause. This source of irregularity may, ho
corrected by fixing a disc of iron, called a *compensator*, in such a position with
the compass, that its action shall be equal and opposite to that of the whol
iron in the ship: the needle will then be free to take up its normal position
influence of the earth's magnetism. It is, however, found better in practice
the compensator in such a position that it shall produce an action equal t
the iron in the ship, and *in the same direction*, so that, when placed in positi
double the deviation produced by the iron in the ship: the amount of this
will thus be ascertained, and may be allowed for. This great service to nav
the invention of Mr. Barlow, of Woolwich.

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the native black oxide of iron is, doubtless, also due to the earth, and the very different powers exhibited by different y, in part at least, be attributed to the different position of he line of the magnetic dip.

Earth's Magnetic force.—The magnetic force of the nary magnet, is of different intensity in different parts. The rent places are measured by counting the number of oscilla- e by a magnetic needle: for these vibrations are subject to a pendulum, being isochronous when small, and the squares ions in a given time being proportional to the force which back to its position of equilibrium.

be made either with the dipping or the horizontal needle. s disturbed from its normal position of equilibrium, it is n by the whole force of the earth's magnetism: so that, if the l magnetic forces at any two places are devoted by F, F', and of oscillations made in a given time by n, n', we have, for the orces,

$$F : F' = n^2 : n'^2.$$

n the other hand, is urged back to its normal position by only force, which becomes less as the magnetic latitude is greater. ng on the needle in the line of the dip, may be resolved l, which is destroyed by the suspension, the other, f, horizon- effective in moving the needle; and if i be the dip at the horizontal force f is equal to $F \cos i$. Hence, for any two ntensities are F, F' the angles of dip i, i', and the numbers ve the relation,

$$\frac{n^2}{n'^2} = \frac{f}{f'} = \frac{F \cos i}{F' \cos i'}.$$

$$\frac{F}{F'} = \frac{n^2 \cos i'}{n'^2 \cos i'}.$$

or, $i = o$, $\cos i = 1$, and therefore $f = F$; at the magnetic fore $f = 0$: in fact, at these points, the horizontal needle ferently; and near the poles, the force which directs it is very ns cannot be depended upon. But, excepting in these high esults obtained with the horizontal needle are more trust- d with the dipping-needle, on account of errors affecting the ct horizontality in the axis, the friction on the supports, tal needle is easily suspended by a thread of unspun silk, fect freedom of motion. [For full details on the construc- observations on terrestrial magnetism, see Becquerel, *u Magnétisme*, Paris, 1840, tome vii. The atlas to that work f these instruments, and maps representing the directions and parallels on the surface of the globe. See also Daguin, ii. pp. 27, 55.]

increases with the latitude. Humboldt found a point of magnetic equator in Northern Peru. This value is gene- which the magnetic intensities at other parts of the globe are g table.

atitude.	Magnetic intensity.	Locality.	Date.	Latitude.	Magnetic intensity.
0° 0′	1·087	Brussels . .	1829	50° 52′N	1·374
0 25 N	1·294	Berlin . .	1829	52 51	1·366
0 43	1·803?	Christiania .	1820	59 55	1·419
0 50	1·274	Petersburg .	1828	59 66	1·410
5 46	1·333	Baffin's Bay .	1818	62 43	1·590
8 52	1·348	Spitzbergen .	1823	79 40	1·567

he magnetic intensity was 1·372 in London in 1827 (Sabine) e intensity at the north magnetic pole is 1·624; at the south Sir James Ross, it is 2·052. The smallest intensity, 0·706, t 19° 59′ S. and 10·2′ E. (from Paris).

ade by British observers, an absolute unit of intensity has g with a second of time, a foot of space, and a grain of mass.

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The magnetic intensity on this scale at London is at present 10·29; t
is a force capable of generating in one second, in a mass of one grain, a
feet per second. The total force, expressed in absolute units, has been
at different parts of the earth's surface from about 6·4 to 15·8. (Sab
Manual of Scientific Inquiry; ed. 1859, p. 89.)

The mean amount of the total force in England, deduced by Sabine fr
survey already referred to (p. 780), for 1st January 1860, is 10·332
10·225, having been observed at St. Leonard's, and the maximum, 10·62
(lat. 56° 22; long. 3° 50′ W.). The direction of the *isodynamic l*
equal intensity, in England, at the above date, was from N. 57° 35′·7 E. t

The isodynamic lines differ considerably from the isoclinal lines, o
dip, but bear considerable resemblance to the isothermal lines; wh
probable that the magnetic intensity of the earth (like that of an o
is affected by heat. (For a chart of these lines, see Becquerel, *loc. cit.*)
Gauss, there are in each hemisphere two points of maximum magneti
ciding with the points of greatest cold, but not with the magnetic pole
the dip and declination of the needle.

Variations of the Magnetic Elements.

The declination, dip, and intensity at any point of the earth's surfac
continual variations, both regular and irregular; and the regular
two kinds: secular variations, of considerable amount, and exten
periods of time; and periodic variations, of small amount, and runni
phases at short intervals.

Variations of the Declination.—1. *Secular.* The earliest exact obse
magnetic declination were made at London in 1576, and at Paris in 158
in 1576, it was 11° 15′ to the east; from that time it diminished till 1
it was nothing, the needle then pointing due north and south; it then b
attaining its maximum of 24° 36′ in 1800. In 1831 it had diminishe
it is now (in 1864) 20° 45′ W. At Paris it was 11° 30′ E. in 1580, 0 in 1
maximum of 22° 34′ W. in 1814, and had diminished to 20° 25′ W. in
Cape of Good Hope, the declination in 1605 was 0° 30′ E., became n
1605 and 1609, then westerly, attaining its maximum of 25° 40′ W. a
all cases the declination given for each year is the mean of those obtain
and for each month, so as to eliminate the diurnal and annual variatio

2. *Annual.*—The declination of the needle is subject to small an
which were discovered by Cassini in 1780. At Paris and London, it i
the vernal equinox, diminishes from that time to the summer solstic
again during the nine following months. The annual variation does n
15′ to 18′. It is also different in amount at different epochs. At Lon
to 1820, it was reduced almost to nothing; at which time, also, the a
was extremely slow, being near its maximum.

3. *Diurnal.*—The diurnal variations of the declination were discovere
in 1722. In Europe, the north pole of the needle begins to move west
and continues moving in the same direction till an hour or two after noo
it returns and regains its original position at about 10 P.M., at which
night. It appears, then, that the westerly declination is greatest duri
part of the day. The amplitude of these movements is very small, an
ferent times of the year, being sometimes from 20′ to 25′, at other time
5′ or 6′. It also becomes less as we approach the magnetic equator: thu
of Rawak it never exceeds 3′ or 4′.

The periodic variations of the declination are the result of the
of two distinct variations,—one depending on the horary position of the
on his distance from the equator, the latter constituting the annual vari

Variations of the Dip.—The secular variations of the magnetic dip
amount than those of the declination. At Paris, in 1671, when the
observed, it was 73° 0′, and has since been continually diminishing; i
66° 35′. In London also the dip has continually diminished since 172
per annum. In August, 1821, it was 70° 2′·81; in May, 1838, it was
August and September, 1854, it was 68° 31′·13; it is now 68° 15′.

The dip likewise exhibits annual and diurnal variations, being, accordi
about 15′ greater in summer than in winter, and 4′ or 5′ greater before n

Variations of the Intensity.—It is not yet distinctly ascertained
magnetic intensity of the earth exhibits secular variations: indeed, the
the question is attended with very great difficulty, inasmuch as it req
needles used should preserve their magnetic power unaltered through

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a condition scarcely possible to fulfil for any great length
indeed, by a peculiar method of observation which is inde-
needles used, that the magnetic intensity at Göttingen has
several years; but the time over which these observations
ort to warrant any general conclusion on the subject. It is,
hat the declination and dip should change at any place
variation in the intensity. By absolute measurements
April, 1857, it appears that the total force had increased
862, at the average rate of 0·00125 annually.

ensity are more easily observed. In studying these, it is
he variations of the horizontal and vertical components of
rizontal component exhibits an hourly variation, which is
tary variations—one diurnal, the other semi-diurnal. The
al variation increases with the latitude, and is nothing at
hrough which it passes depend on the angular distance of
neridian. In mean latitudes, the curve which represents
al component is similar to that of the diurnal variation of
behind it. The semi-diurnal period is scarcely perceptible
in distinctness at higher latitudes.

ical component of the intensity follow the same periods as
onents.

Perturbations of the Magnetic Elements.—The magnetic
ation-needle, frequently experiences accidental deviations,
ss from its normal position for various intervals of time,
s. Some of these disturbances may be traced to known
borealis, earthquakes, and volcanic eruptions. But few
le on the perturbations arising from the two latter causes,
ensible effects at small distances only. The deviations
disturbances rarely exceed a fraction of a degree, and the
e position as soon as the disturbing cause has ceased to act.
urora borealis with certain perturbations of the magnetic
10 by Celsius and Hiorter. During the occurrence of
needle is seen to deviate from its normal position, even in
self is not visible; so that the inspection of the needle often
ence of an aurora, no trace of which can be directly seen.
does not exceed 20′; but it is greater in the Arctic regions,
ion has been principally studied. The culminating point of
situated in the magnetic meridian of the place, and the
h the streams of light converge is situated on the pro-
dip. So long as the auroral arch is stationary, the needle
s soon as the arch begins to throw out streamers, the needle
several degrees. The effects are more decided in propor-
ie aurora. The dip and the intensity are likewise affected
declination.

netic observatories, in which the motions of the needle are
ed to the discovery of perturbations which cannot be attri-
ing causes. One of the most remarkable facts brought to
ements of the powerful magnets with which these establish-
the magnetism of the earth is in a state of constant fluc-
e sea. Hence, in studying the diurnal, annual, and secular
n, &c., it is necessary to take the mean of a large number
eliminate the irregular disturbances and bring out the

phenomenon is the simultaneous occurrence of magnetic
countries. Thus, Sabine mentions a magnetic disturbance
ly at Toronto, the Cape, Prague, and Van Diemen's Land.
ic perturbations is so exact, that it has been proposed to
ining the longitude of the place of observation. Humboldt
rved some remarkable perturbations recurring at the same
nights. These simultaneous perturbances have received
s.

urbations extending to small distances only. Humboldt
erved in the Saxon mines, but was imperceptible at Berlin.
simultaneously from Sicily to Upsala, were imperceptible

RICITY. The development of electricity by magnetic
ii. 451.)

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MAGNETOMETER. This name is specially applied to devised by Gauss for measuring the intensity of the earth's m Becquerel, *Traité de l'Electricité et du Magnetisme*, tome vii., *de Physique*, iii. 78.)

MAGNIUM. Davy's name for Magnesium: it is also adop *Handbuch*.

MAGNOFERRITE. A compound of ferric oxide and ma or $3MgO.4Fe^2O^3$, occurring in octahedral crystals among the pro of Vesuvius in 1855. Specific gravity about 4·6. (Rammelsb 457; Jahresber. 1859, p. 776.)

MAHOGANY. See *Ure's Dictionary of Arts, &c.* iii. 16.

MAIZE. *Zea Maïs.*—The composition of the grain of this p given in the article CEREALS (i. 825, 827). See also ZEIN. On the see v. Planta (Jahresber. 1860, p. 523). On the growth of ma tions of its constituents, see Stohmann (*ibid.* 1861, p. 734).

MAJORANA. See MARJORAM.

MAKWAR BUTTER. Syn. with GALAM BUTTER (ii. 758

MALACHITE. Native carbonate of copper. (See CARBON

MALACOLITE, also called *Sahlite, Pyrgom, Fassaite.*— consisting of silicate of calcium and magnesium, with more or le small portion of the bases being frequently also replaced by wate

MALACONE. A mineral having the form of zircon, and composition. Hardness = 6·5. Specific gravity = 3·9 to 4·05. to subresinous; powder reddish brown or uncoloured.

Analyses.—a. From Hitterö, Norway, by Scheerer (Pogg. Ann the Ilmengebirg, by Hermann (J. pr. Chem. liii. 323).—*c.* From Vienne, by Damour (*Rammelsberg's Mineralchemie*, p. 891):

	SiO^2	ZrO^2	Fe^2O^3	Mn^2O^3	YO	CaO	MgO
a.	31·31	63·40	0·41	. .	0·34	0·39	0·11
b.	31·87	59·32	3·11	1·20	. .	. .	. .
c.	31·05	61·44	3·29	0·14	. .	0·08	. .

These analyses lead to the formula $3(ZrO^2.SiO^2).H^2O$ or requires 32·60 per cent. SiO^2, 64·22 ZrO^2, and 3·18 water.

MALAMIC ACID.
MALAMIDE. } See MALIC ACID, AMIDES OF.

MALAMYLIC ACID. Syn. with AMYL-MALIC ACID. (Se

MALANIL. Syn. with PHENYL-MALIMIDE.

MALANILIC ACID. Syn. with PHENYL-MALAMIC ACID.

MALANILIDE. Syn. with PHENYL-MALAMIDE.

MALEIC ACID. $C^4H^4O^4 = \left.\begin{matrix} C^4\overset{''}{H}^2O^3 \\ H^2 \end{matrix}\right\} O^2$. *Pyromalic ac*

(Lassaigne, Ann. Ch. Phys. [2] xi. 93.—Pelouze, *ibid.* lvi. 7 Pharm. xi. 276.—Büchner, *ibid.* xlix. 57.—Kekulé, Ann. Ch. ii. 85; Jahresber. 1861, p. 364; 1862, pp. 308, 319.—Gm. viii. 15 with fumaric acid, and differing from malic acid ($C^4H^6O^5$) by 1 duced, together with fumaric acid, by the dry distillation of malic been found ready formed in any plant. Equisetic acid, obtained fr *tile*, was for some time regarded, on the authority of Regnault, as acid; but Baup has shown that it is really identical with aconiti

To prepare maleic acid, malic acid is heated in a capacious re about a fourth, the distillation being pushed on rapidly. Water t afterwards, white vapours of maleic acid, which condense in the the residue in the retort thickens, the fire must be withdrawn; goes on of itself for some time, till a solid residue is left in the fumaric acid. An additional quantity of maleic acid may be o this residue at a higher temperature; but the product is then col purify. By evaporating the distillate at a gentle heat, the male crystals.

Maleic acid crystallises in oblique, rhomboïdal prisms, generally modified with octahedral faces. It is colourless and inodorous; i soon excites a very unpleasant sensation of nausea. It is very so alcohol; dissolves also in ether. The aqueous solution reddens li

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en vessel, it creeps up the sides and effloresces in forms like

about 130°, and the liquid acid begins to boil at about 160°, being
er and maleic anhydride, $C^4H^2O^3$. If the acid, instead of
o 160°, be boiled in a very long and narrow tube, so that the
obliged to fall back upon it, the maleic acid is converted into
naric acid. The same transformation takes place on heating
d at both ends.

nverted into fumaric acid by heating it with concentrated *hydriodic*
or by boiling for some time with dilute *nitric acid*. When
the fumaric acid is subsequently converted into succinic acid.
ct with water and *sodium-amalgam* takes up hydrogen, and is
ic acid:

$$\underset{\text{Maleic acid.}}{C^4H^4O^4} + H^2 = \underset{\text{Succinic acid.}}{C^4H^6O^4}$$

tion takes place when maleate of calcium is fermented in con-
ssaignes.)

r and *bromine*, maleic acid is converted into dibromosuccinic
another more soluble acid of the same composition, called iso-
cid. (Kekulé.)

ic acid is dibasic, forming *acid salts*, $C^4H^3MO^4$, and *neutral salts*,
ates bear considerable resemblance to the fumarates, with which
they may be distinguished by the difference of solubility between
l: solutions of the maleates are not precipitated by other acids,
ineral acid to the solution of a fumarate (sufficiently concen-
precipitate of fumaric acid is formed.

onium.—α. The *neutral salt* is obtained as a crystalline jelly by
solution of the acid with ammonia, and evaporating over lime
cohol added to the concentrated aqueous solution throws down
a white crystalline powder, which may be dried by repeated
and pressing between paper, but, when exposed to the air,
ous and deliquescent (Büchner). This salt does not precipi-
ichloride of iron, a character which distinguishes it from the
conitic acid.

btained by exactly neutralising a known quantity of the aqueous
en adding an equal quantity of the acid, and evaporating to the
gentle heat. It forms crystalline laminæ, which are permanent
s, and give off nothing at 100°: their solution evolves ammonia
y easily soluble in water, but not in alcohol.

um. α. *Neutral salt.* $C^4H^2Ba''O^4.2H^2O$.—1. Maleic acid forms
ulverulent precipitate, which disappears on the addition of a small
but reappears after a while in shining scales (Lassaigne).
he precipitate is converted into the crystalline scales, even with-
On adding a saturated solution of baryta-water to the concen-
e precipitate redissolves at first in the excess of acid; even when
has been added to neutralise the acid, the precipitate is but
w minutes, the whole solidifies to a tremulous gelatinous mass,
aluminium, which, after being pressed, dries up to small crystal-
crystals are obtained still more distinct on evaporating the
nault).—2. The salt is also obtained by adding carbonate of
eous acid, as long as effervescence continues, then filtering hot,
n to crystallise (Büchner).—3. The concentrated acid added
rows down a white crystallo-granular, neutral salt. Part of the
dissolved in the acetic acid which is set free, and may be preci-
his portion is also crystallo-granular, and has the same compo-
he salt crystallises from its aqueous solution on cooling, in small
in stellate groups; and the solution, when evaporated at a tem-
ing point, becomes covered with a crystalline crust (Büchner).
ing in the air, lose 5·62 per cent. (1 at.) water at 100° (Büch-
at 150° (Regnault). They dissolve sparingly in cold water
according to Regnault), with tolerable facility in boiling water,
ic or acetic acid, easily also in excess of baryta-water.

$a''O^8.5H^2O$.—Obtained by saturating the aqueous acid with the
urating a known quantity of the boiling aqueous acid with car-
adding another equal quantity of acid to the hot filtrate. The
ls, after rather strong concentration, indistinct crystals, which

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redden litmus, give off the whole of their water of crystallisation (
100°, and dissolve in water, but not in alcohol. (Büchner.)

Maleates of Calcium.—α. The *neutral salt*, $C^4H^2Ca''O^4.H^2O$, i
ing to Büchner, in small needles very soluble in water, but insol
saturating the boiling aqueous acid with carbonate of calcium and
filtrate at a gentle heat. According to Pelouze, a solution of ma
mixed with concentrated aqueous chloride of calcium remains cle
days deposits needles which are but sparingly soluble in water.
boiling acid with carbonate of calcium and evaporating the filtrat
small needles are obtained united in saline crusts; they do not gi
100°; dissolve readily in water, but not in alcohol (Büchner).
mented with casein, is converted into succinate of calcium. (Dess

β. The *acid salt*, $C^8H^6Ca''O^8.6H^2O$, is formed by dissolving th
quantity of the aqueous acid equal to that which it already contain
the solution somewhat strongly. It forms long rhombic prisms, w
in the air, redden litmus, give off 24·1 per cent. ($\frac{5}{6}$ at.) of water a
readily in water, but not in alcohol. Oxalic acid added to the solu
the lime. (Büchner.)

Maleate of Copper, $C^4H^2Cu''O^4$.—1. On boiling carbonate of co
acid, the filtrate is found to contain in solution but a small quan
crystallises out on evaporation; if the residue on the filter be freed
of copper still adhering to it, by means of dilute acetic acid, whi
small quantity of the maleate, the latter remains in the form of cry
washed with cold water.—2. When a concentrated solution of a
mixed with an equivalent quantity of maleic acid, and evaporated
acetic acid goes off, and maleate of copper crystallises out; the cryst
with cold water. The light blue crystals are but sparingly soluble i
boiling heat, but dissolve readily in aqueous ammonia. (Büchner

Maleate of Cuprammonium.—The dark blue solution of m
ammonia may be evaporated, even near its boiling point, without lo
alcohol added to the concentrated solution precipitates the compoun
neutral, azure-blue, crystalline powder, which gives off ammonia
potash, and dissolves readily in water, but not in alcohol. (Büchn

Maleate of Iron (ferricum).—Neither maleic acid nor maleate
pitates ferric acetate; neither is ferric chloride precipitated by male
A boiling solution of maleic acid dissolves a small quantity of ferr
a brownish solution which yields a red-brown syrup on evaporation

Maleate of Lead, $C^4H^2Pb''O^4.3H^2O$.—1. Free maleic acid f
with neutral acetate of lead (Lassaigne), but not with the nitrate
the solution is dilute, the white precipitate changes in a few mi
micaceous laminæ; but if the solution is concentrated, and the
excess, the mixture solidifies to a tremulous mass, which changes
on the addition of water—into crystalline laminæ, which with diffi
16·5 per cent. (3 at.) water (Pelouze).—2. Maleate of potassium
lead, throws down white flakes; these soon change to a translucen
then, when washed upon a filter, diminish considerably in volume,
into small pearly needles (Lassaigne). The salt dissolves in
acetic acid. (Braconnot.)

Maleates of Magnesium. α. *Neutral salt*, $C^4H^2Mg''O^4$ (at 10
acid saturated at the boiling heat with carbonate of magnesium, yie
leaves on evaporation a tumefied spongy mass perfectly soluble in
centrated solution of the salt yields with alcohol a bulky precip
hygrometric, but gives off 27·36 per cent. water at 100°: it is very s
in dilute alcohol.

β. *Acid salt*, $C^8H^6Mg''O^8.6H^2O$.—By cooling a solution of 1 at.
and 1 at. maleic acid in hot water, small transparent and colourles
are obtained, which redden litmus strongly, grate between the teet
salts, and dissolve readily in water, but are insoluble in alcohol.
off 34·95 per cent. water.

Maleate of Nickel, $C^4H^2Ni''O^4.H^2O$.—By boiling the aqueous s
of nickel, and evaporating the dark green, slightly acid filtrate,
obtained, and ultimately apple-green crystals and crystalline c
alcohol, but readily soluble in water, (Büchner.)

Maleates of Potassium. α. The *neutral salt*, $C^4H^2K^2O^4$ (at
by saturating the acid with carbonate of potassium, and evaporating

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ed aqueous solution, this salt is precipitated as a granulo-

.H^2O.—On saturating the acid with carbonate of potassium, of maleic acid, and cooling the solution, after sufficient con- ained in small crystals very soluble in water; the solution is insoluble in alcohol. It does not give off any water

to a concentrated solution of the neutral potassic salt, no nediately, but the acid salt is deposited after some time.

a. Neutral, $C^4H^2Ag^2O^4$.—The acid gives no precipitate with ate of potassium or ammonium throws down a white preci- connot). The white precipitate obtained with an alkaline hours to tolerably large, transparent and colourless crystals, re; after drying, it detonates slightly on the application of

(at 100°).—Obtained in fine colourless needles by mixing a n nitrate of silver, and evaporating at a gentle heat.

a. Neutral, $C^4H^2Na^2O^4$.—The aqueous acid saturated with vaporated, yields a magma of needles on cooling. The salt is us solution by alcohol, as a crystalline powder. It is not

$NaO^4.3H^2O$, obtained like the acid potassium-salt, forms ly soluble in cold, more soluble in boiling water, insoluble as an acid reaction. The crystals contain 28·3 per cent. h they give off at 100°.

$C^4H^2KNaO^4.H^2O$.—On neutralising an aqueous solution of bonate of potassium, then evaporating and cooling the syrup, tained, floating in a gelatinous mother-liquid. On precipi- eous solution with absolute alcohol, and setting the crystal- act with absolute alcohol, there is finally obtained a white, line powder, which gives off 9·13 per cent. (2 at.) water at er cent. potash, and 17·64 per cent. soda. (Büchner.)

tassic nor the ammonio-sodic salt has yet been obtained.

ium.—*a*. The *neutral salt*, $C^4H^2Sr''O^4.5H^2O$, forms silky $C^8H^6Sr''O^8.8H^2O$, obtained like the corresponding barium- gular prisms, which are limpid, and acid to litmus-paper. r, but insoluble in alcohol. It gives off the whole of its 00°. (Büchner.)

$[^2Zn''O^4.2H^2O$.—On boiling the aqueous acid with carbonate e filtrate at a gentle heat, gelatinous flocks are deposited, rystalline on standing. The solution when heated, deposits ts. The crystals do not lose anything at 100°; they are insoluble in alcohol. (Büchner.)

ostitution-derivatives of Maleic Acid.

ld substitution-products by the direct action of chlorine or ave been obtained by indirect processes, having the compo- -products, and analogous to maleic acid in their properties.

These compounds are produced by the decomposition of of succinic acid.

cid, $C^4H^3BrO^4$.—Of this acid there are four modifications. d bromomaleic acid, is obtained, as an acid barium-salt, tion of dibromosuccinate of barium:

$$\left.\begin{matrix}C^4HBrO^2)''\\ a''\end{matrix}\right\}O^2 \quad = \quad \left.\begin{matrix}C^4HBrO^2)^2\\ H^2Ba''\end{matrix}\right\}O^4 \quad + \quad Ba''Br^2.$$

ned from this barium-salt in the usual way, crystallises readily f prismatic crystals. It melts between 125° and 126°, and is to water and bromomaleic anhydride, an oily liquid, fication, boils at about 212°, and in contact with water is slowly

nverted by sodium-amalgam into succinic acid. It does not, d tartaric acid when boiled with lime. When heated to 100°

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with water and *bromine*, it yields a crystallisable, deliquescent acid, be **dibromotartaric acid**:

$$C^4H^2BrO^4 + 2Br^2 + 2H^2O = C^4H^4Br^2O^6 + 3H$$

Bromomaleic acid is dibasic. Its salts usually form nodules of The *silver-salt*, $C^4HBrAg^2O^4$, separates, on mixing bromomaleate o nitrate of silver, as a white amorphous precipitate, which may be cr decomposition from boiling water. (Kekulé.)

Isobromomaleic acid. This acid, isomeric with the preceding, is pr isodibromosuccinic acid to 180°, or by boiling and evaporating its aq

$$C^4H^4Br^2O^4 = C^4H^2BrO^4 + HBr;$$

also by boiling isodibromosuccinic anhydride with water.

Isobromomaleic acid, is very much like bromomaleic acid, but m temperature, viz. 160°. Its *silver-salt* is easily decomposed by boili

Isobromomaleic anhydride, $C^4HBrO^2.O$, is obtained, with evolution acid, on heating isodibromosuccinic anhydride to 180°. It is crysta

Two other acids having the composition of bromomaleic acid, viz *bromomaleic acid*, are found, together with dibromosuccinic acid, in portion of the secondary products resulting from the action of bromin Both are crystallisable and very soluble in water. The former mel the latter at 172°. Their silver-salts are more stable than that of iso

Dibromomaleic acid, $\left.\begin{matrix}C^4Br^2O^2\\H^2\end{matrix}\right\}O^2$.—This acid is produced, together with dibromosuccinic acid, and the two last-mentioned modi bromomaleic acid, by the action of bromine on succinic acid. It is mother-liquors, and may be obtained therefrom by distillation and a the distillate. It is probably a product of the decomposition of tribromosuccinic acid.

Dibromomaleic acid crystallises in nodular groups of large needles soluble, and volatilises with the aqueous vapours. Melts at 112°. It *salts* are crystalline precipitates, which detonate when heated; the a percussion. (Kekulé, *Lehrbuch d. org. Chemie*, ii. 315.—Ann. Ch.

Chloromaleic acid. $\left.\begin{matrix}C^4HClO^2\\H^2\end{matrix}\right\}O^2$.—Obtained by the action o phosphorus on tartaric acid. When 1 pt. of tartaric acid is heated the pentachloride, large quantities of hydrochloric acid are evolved, t chloride of phosphorus, which must be removed by prolonged hea current of air. The residue consists of oily *chloride of chloromaleyl*, C is resolved by water into hydrochloric and chloromaleic acids.

The reaction may be explained as follows:—The first product of th chloride of phosphorus on tartaric acid is the tetrachloride of the ra

$$\underset{\text{Tartaric acid.}}{\left.\begin{matrix}C^4H^2O^2\\H^4\end{matrix}\right\}O^4} + 4PCl^5 = \underset{\text{Tetrachloride of tartryl.}}{C^4H^2O^2.Cl^4} + 4POCl^3 +$$

and this tetrachloride, which is identical with dichloride of dichlorosu by heat (in a manner analogous to the decomposition of isodibromosuc mentioned) into hydrochloric acid and dichloride of monochloromale

$$\underset{\text{Dichloride of dichloro-succinyl.}}{C^4H^2Cl^2O^2.Cl^2} = \underset{\text{Dichloride of chloromaleyl.}}{C^4HClO^2.Cl^2} + HCl.$$

Chloromaleic acid forms white microscopic needles, soluble in wat heat. It is dibasic. The *lead-* and *silver-salts* are crystalline precip and Duppa, Ann. Ch. Pharm. cxv. 105.)

Isomaleic acid, $C^4H^4O^4$.

Isomalic acid (p. 794), treated with pentachloride of phosphorus, which, when in contact with water, is converted into this acid, iso acid.

Isomaleic acid is crystallisable, less soluble in water than maleic than fumaric acid. The *neutral potassium-salt* forms deliquesce *lead-salt* is an amorphous precipitate. The *silver-salt* is very soluble solution, when boiled, deposits metallic silver. (Kämmerer, J. p 321; Jahresber. 1863, p. 379.)

MALEIC ANHYDRIDE. $C^4H^2O^3 = C^4H^2O^2.O$. (Pelouze,

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uppl. ii. 87.)—This compound is obtained by rapidly distil-
ying the product several times, the first portion of the distil-
ed. It is a white crystalline mass, which melts at 57°, and
with water it is converted into maleic acid.
directly with bromine, producing a substance which has the
citinic anhydride, $C^4H^2Br^2O^2.O$, is converted by water into
d is resolved at 180° into hydrobromic acid and isobromo-
ulé.)

$I^6O^5 = \left.\begin{matrix}(C^4H^3O^2)''\\H^2\end{matrix}\right\}O^3$. (Gm. x. 205.—Gerh. i. 787.)—This

eele in 1785, but its composition was first correctly deter-
Ch. Pharm. xxvi. 166). It is very widely diffused in the
contained in plants, sometimes in the free state, sometimes
n-, calcium-, or magnesium-salt. It is found in abundance,
unripe apples, in the fruits of the barberry, sloe, elder,
gooseberries, cherries, bilberries, strawberries, raspberries,
its. It is likewise found in the roots of marsh-mallow,
ny, liquorice, primrose, and madder; in carrots and potatoes;
aconite, belladonna, hemp, celandine, holy thistle, lettuce,
ouse-leek, tansy, thyme, valerian and melilot; in the flowers
ullein; in pine-apples and grapes; in the seeds of carraway,
and pepper; in asafœtida, opopanax, myrrh, &c.
in plants, exerts a rotatory action on polarised light. An
me composition and properties, including the rotatory power,
Piria (Ann. Ch. Phys. [3] xxii. 160), by the action of nitrous
active aspartic acid; but, by acting with nitrous acid upon
duced by the metamorphosis of fumarimide), Pasteur has
malic acid destitute of rotatory power (Ann. Ch. Phys. [3]

ording to Berzelius, among the residues of the preparation
(Ann. Ch. Pharm. c. 1) could not detect malic acid in these
, glyoxylic acid.

berries of the Mountain-ash. These likewise contain small
citric acid, especially while very unripe. (Liebig.)
ash berries, not quite ripe, after being pressed, boiled up and
d with carbonate of potassium, leaving, however, a sufficient
litmus pretty strongly; then precipitated by nitrate of lead
f lead, if carbonate of potassium is not used); set aside for
precipitate is completely converted into small needles; these
dmixed mucous or flocculent compound of lead-oxide and
s particularly abundant when acetate of lead is used) by
l water; and, lastly, well washed with water.—*a.* The needles
y of dilute sulphuric acid not sufficient to decompose the
ny granular deposit continues to subside; the uniform pulpy
sulphide of barium, till a filtered sample is found to contain
(the sulphide of lead then acting as a decolorising agent);
ed with excess of carbonate of barium; the liquid again
e of barium remaining on the filter); the baryta precipitated
ul addition of dilute sulphuric acid; and the filtrate, which
ither with sulphuric acid or with chloride of barium, evapo-
point. If the filtrate should become turbid on addition of
evaporated down, the residue exhausted with alcohol; the
emaining malate of barium; and again evaporated.—*b.* Or
late of lead are boiled with a slight excess of dilute sulphuric
nto two equal portions; one portion exactly neutralised with
n then added; and the reddish liquid evaporated and cooled;
urless crystals of acid malate of ammonia, which may be
y recrystallisation. These crystals are then precipitated by
precipitate, after thorough washing, is decomposed by sul-
(Liebig.)
lic acid may be obtained from house-leek, from cherries or
s of *Rhus coriaria*, from the stems of rhubarb, from apples,

us solution of malic acid concentrated to a syrup, and then
n place, yields groups of colourless shining needles or prisms
elt at 83° C. (Pelouze), at 100° (Pasteur), and do not

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suffer any loss of weight at 120°. They are odourle
quesce in the air. Malic acid is soluble in alcohol.

The aqueous solution of active malic acid rotates the pl
ray to the left: [s] = − 5°. Some of its salts poss
rotatory power. The presence of acids, whether mi
tendency to lævo-rotation. (Pasteur.)

Decompositions.—1. The acid heated for some hour
retort placed in the oil-bath, is resolved, without any e
into water, maleic acid, which passes over in the liq
crystallises soon afterwards, and about an equal qua
part of which distils over, while the rest remains in th
line mass. If the malic acid be suddenly heated to
that temperature, a comparatively large quantity of m
150°, the malic acid is very slowly, but almost comp
fumaric acid. The first product of the decompositio
maleic acid, which, however, if the heat be not quickl
sation, is converted into fumaric acid. (Pelouze.)

If a strong fire be made to act immediately on the
brown, and yields, together with maleic and fumaric
bonic oxide and carbonic anhydride, empyreumatic oi
regarded as decomposition-products of the maleic and
(Lassaigne).—2. In the open fire, the acid burns w
3. The acid in combination with potash is decomposed
bromoform (Cahours, Ann. Chim. Phys. [3] xix. 5
verts it into oxalic acid, with evolution of carbonic anh
5. By the action of *reducing agents* it is converted i
tion takes place readily on heating it with concentrated h
Ann. Ch. Pharm. cxiv. 106); also when malate of ca
with yeast. (Piria, *ibid.* lxx. 102; Liebig, *ibid.* 104
6. By slow oxidation in the cold with *acid chromate*
malonic acid (Dessaignes, Ann. Ch. Pharm. cvii. 2

$$\underset{\text{Malic acid.}}{C^4H^6O^5} + O^2 = \underset{\text{Malonic acid.}}{C^3H^4O^4} + H^2$$

When heated with chromate of potassium and sulphuri
as carbonic anhydride (Döbereiner). Boiled in
peroxide of manganese, it yields a distillate containing
Pharm. cxiii. 14).

7. Malic acid gently heated with excess of *potassic*
and acetic acids:

$$C^4H^4K^2O^5 + KHO = C^2H^3KO^2 +$$

When malate of calcium (1 pt.) is heated with *penta*
chloride of fumaryl passes over (Perkin and D
malic acid (1 at.) is heated with the pentachloride (2 a
and the product is decomposed with water, fumaric aci
ibid. c. 327.)

Malates.—Malic acid, though most probably tris
tution of its amides (p. 796), contains only 2 at. hydro

may therefore be conveniently represented by the formu

of glycollic acid, which is diatomic but monobasic), and

by the formulæ $\left.\begin{matrix} H \\ M^2 \end{matrix}\right\}O^3$, and $\left.\begin{matrix} H \\ H.M \end{matrix}\right\}O^3$. Malic aci

acid salts.

The active and inactive modifications of malic aci
inactive salts. The former sometimes exhibit hemihedr
always holohedral.

The malates heated to 200° give off water, and are co

$$C^4H^4M^2O^5 = C^4H^2M^2O^4$$

Nearly all malates are soluble in water. A solution o
precipitated by *lime-water* or *chloride of calcium*, either
on the addition of alcohol, a white precipitate of calc
malate of calcium is also precipitated by long boiling of

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f lime. With *acetate of lead*, malic acid forms a white precipi-
malic acid and in ammonia: this precipitate when heated in its
a semifluid, transparent mass. Malates are not blackened by
lphuric acid; this reaction distinguishes malic from citric and

nium.—The *neutral salt* is a transparent gum, which reddens
nent in the air, and dissolves readily in water, forming a solu-
cipitated by potash or ammonia. There is also a *basic salt*
er.

nium.—*a*. The neutral salt is very soluble and uncrystalli-

$[C^4(NH^4)O^5]$, is prepared by treating malate of lead with dilute
are to avoid an excess of acid, filtering, dividing the liquid into
e with ammonia, then adding the other, and evaporating to a
red with optically active malic acid crystallises in fine trans-
g to the trimetric system, with well-defined and strongly reflect-
combination, $\infty P . \breve{P}\infty . \frac{1}{2}\breve{P}\infty$, sometimes with hemihedral

of the faces, $\infty P : \infty P = 71° 36'$; $\frac{1}{2}\breve{P}\infty : \frac{1}{2}\breve{P}\infty$, in the plane of
vertical axis = 137° 35′; $\breve{P}\infty : \breve{P}\infty$ in the same plane = 103° 36′.
icular to the faces ∞P. The salt, when crystallised from pure
idulated with nitric acid, is never hemihedral; but the crystals
when melted till they begin to decompose, and then recrystal-
, therefore, that the action of heat gives rise to the formation
products which induce the development of hemihedral faces.
rystals = 1·55 (that of water at 12·5° = 1). The crystals dis-
ter at 15·7°. The solution deflects the plane of polarisation to
r for 100 millimetres: $[\alpha] = -6°$ or $-7°$. If the salt is dis-
becomes dextro-rotatory: $[\alpha] = +5·6°$. By dry distillation, it
ves an insoluble residue of fumarimide (ii. 746). Ammonia
ier with the water, and the residue contains fumaric and maleic
lic acid both active and inactive.

salt of inactive malic acid forms two kinds of crystals.—(*a*) The
d first yields crystals having the same composition as the active
e same form, with exception of the hemihedral faces, which are
er-liquor separated from these crystals deposits, after a while,
crystals containing 2 at. water more than the salt *a*, and be-
linic system. Ordinary combination, $\infty P . [\infty Pn] . [P\infty]$.
$P : \infty P$ in the plane of the clinodiagonal and principal axis
$\infty P = 149° 33'$; $[P\infty] : [P\infty]$ in the plane of the clinodiagonal
27° 20′; $[P\infty] : \infty P = 85° 22'$ and 119° 22′. Angle of the
6′. No hemihedral faces. Inactive acid malate of ammonium
in the same manner as the active salt.

of ammonium unites in atomic proportion with acid dextro-
the inactive salt does not.

nony.—The neutral salt has not been obtained.

and Ammonium is obtained, according to Pasteur, by boiling a
of ammonium with antimonic oxide. The liquid left to evapo-
salt in large crystals, having the hemihedral faces very fully
n is dextro-rotatory; for 100 millimetres: $[\alpha] = +115·47°$.

and Potassium is obtained in the crystalline state by saturating
a with antimonic oxide. Neither of these double salts has been

m. *a*. *Neutral salt*, $C^4H^4Ba''O^5.2H^2O$?—It is difficult to saturate
ate of barium, so completely that the liquid shall no longer
The solution evaporated in a vacuum deposits transparent
per, and giving off 10·6 per cent., water at 220°. The solution
hite crusts of the anhydrous salt, having no appearance of crys-
solutely insoluble in water whether cold or boiling, but dissolve
e of nitric acid; the solution thus formed is not precipitated by

stallisable and more soluble than the preceding.

m. *a*. *Neutral salt*, $C^4H^4Ca''O^5$.—1. Malic acid does not become
excess of lime-water (Braconnot, Ann. Ch. Phys. [2] li. 331;
n in concentrated solutions and on the application of heat,—a

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character by which malic is distinguished from citri
xxxi. 210; Winckler). The acid neutralised with li
in vacuo (an acid mother-liquid remaining) large, thin,
readily in water, and after drying in vacuo at ordinary
water = 17 per cent. (2 at.) at 180°, and about half
solution, when left to evaporate in the air, again yields
boiling point, deposits a white, granular, nearly insolubl
the laminæ, in parting with half their water, likewise lose
and Menzdorf, Ann. Ch. Pharm. xxvi. 135.)

2. Dilute malic acid agitated in the cold with ex
remains strongly acid; but the filtrate, when boiled, co
granules of the monohydrated neutral-salt, which is n
aqueous malic acid (Richardson and Menzdor
obtained, the neutral salt separates in four-sided pr
teeth, dissolve in 83 pts. of cold and a somewhat
(Lassaigne); or as a granular powder of anhydrou
both in hot and in cold water. (Hagen, Ann. Ch. Ph

3. The same granular powder is thrown down from t
salt by several hours' boiling. (Hagen.)

4. A mixture of aqueous chloride of calcium and neu
after a while, the neutral malate of calcium, in transp
salt scarcely froths up in the fire; it is completely deco
carbonates. It dissolves in 147 pts. of cold water, fo
somewhat like nitre, and in at most 65 pts. of boiling
separate on cooling. (Braconnot.)

5. The solution of acid malate of calcium neutralised
nate, yields, by evaporation at a gentle heat, hard shini
which contain 3 at. water, give off 1 at. water at 10
porcelain, and are completely dehydrated at 150°. (H

6. The granular salt, left to itself in the moist state fo
converted, under circumstances not yet determined, in
crystals, which, after drying in the air, whereby they
22·49 per cent. (3 at.) water at 200°. (Dessaignes
xiii. 243.)

Neutral malate of calcium is easily obtained in the
the acid malate in ammonia, and leaving the solution t
dilute, an abundant crop of crystals is obtained in 24 ho
in hydrochloric acid, and ammonia then added in excess
crystallise.

The crystalline form of this salt is hemihedral, ar
whether dissolved in water or in hydrochloric acid. (
Neutral malate of calcium, kept for some months und
vessel covered with paper, is converted into succinate
winter, crystallised hydrated carbonate of calcium and
wise produced; but in the summer months, the sole
succinate of calcium, which gradually rise above the
while a small quantity of gas is given off. (Dessaign

When a mixture of 4 pts. of malate of calcium, 24 p
(or a smaller quantity of putrefying cheese or fibrin)
tolerably brisk evolution of pure carbonic anhydride t
salt begins in the course of three days to become gr
evolution of gas is terminated, appears under the micr
needles united in stellate groups, and composed o
calcium. The supernatant liquid contains acetate of c

If too much yeast or cheese is used, or if the mixture
is evolved as well as carbonic anhydride, and possibly
case there is obtained but little succinic and acetic,
acid, and a colourless, volatile oil, smelling of apples, v
tilling the liquid; this oil dissolves readily in water, a
by chloride of calcium or carbonate of potassium: i
quantity of chloride of calcium in the dry state. For the
and acetic acid are produced, and pure carbonic an
tion is:

$$3C^4H^6O^5 = 2C^4H^6O^4 + C^2H^4O^2 +$$

For the fermentation, when hydrogen is evolved:

$$2C^4H^6O^5 = C^4H^6O^2 + 4($$

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ogen is consequent on the decomposition of succinic acid:
$^{2}O^{4} = 2C^{4}H^{2}O^{2} + 4CO^{2} + H^{2}$.

remains with the lime. (Liebig, Ann. Ch. Pharm. lxx.

(Ann. Ch. Pharm. lxxviii. 252), malate of calcium fermented
s off nothing but carbonic anhydride, and yields principally
all quantities of succinate, acetate, and carbonate. W. Baer
7) obtained a similar result with the juice of mountain-ash
rbonate of calcium, mixed with beer-yeast, and left to stand
Winckler (Jahrb. pr. Pharm. xxii. 300) found a large
e acid residue of cider, and supposes it to have been formed
ate of calcium contained in the juice of the apples. Reb-
vii. 300) observed that, in the fermentation of malate of
ormed as well as succinic and butyric acids.

ive malic acid is neutralised with lime-water, no turbidity is
of alcohol, the neutral calcium-salt is deposited in white
iling the neutralised aqueous solution, a granulo-crystalline
g the composition $C^{4}H^{4}Ca''O^{5}$, and but sparingly soluble in
When a solution of acid malate of ammonium containing
ith a soluble calcium-salt and excess of ammonia, no pre-
but after 24 hours, transparent crystals united in nodules
$H^{4}Ca''O^{5}$. 5aq. (Pasteur.)

$^{4}O^{5}.8H^{2}O$.—This salt may be prepared from the stems of
not). Also from the berries of *Rhus glabrum* or *copallinum*,
hot water, evaporating the infusion, decolorising it with
purified with hydrochloric acid, evaporating the filtrate
rystallise, and purifying the resulting crystals, if necessary,
rs, Sill. Am. J. xxvii. 294). Tobacco also contains it in
on of the neutral salt in warm dilute nitric acid, deposits
ooling. (Hagen.)

repared with the active acid belong to the trimetric system.
$\breve{P}\infty . \breve{P}\infty . \breve{P}\infty . m\breve{P}\infty$. Inclination of the faces,
$\infty\breve{P}n = 162° 14'$; $\infty\breve{P}\infty : \infty\breve{P} = 133° 17'$; $\infty\breve{P}\infty : \breve{P}\infty =$
3° 30'. Cleavage easy parallel to $\infty\breve{P}\infty$. When crystal-
s not exhibit hemihedral faces; but when crystallised from
have four faces $\frac{mP}{2}$, and for a certain concentration of the
much developed as nearly to obliterate the principal faces
s dissolve in 50 pts. of cold water, and in a much smaller
hey are insoluble in absolute alcohol. They give off 22·37
r at 100°, and are completely dehydrated at 180°.
es the preceding in every respect, excepting that it has no

cid malate of calcium saturated with alkaline carbonates
monio-, *potassio-*, and *sodio-calcic malates;* but they have

. The *neutral salt*, $C^{4}H^{4}Cu''O^{5}.H^{2}O$, is a gummy mass of a
oluble in water.
$''O^{5}.2H^{2}O$, is obtained in fine blue crystals, by saturating
upric hydrate and evaporating at 40°.
$O^{5}.Cu''O.4H^{2}O$, is obtained, as a green insoluble powder, by
with cupric carbonate. The carbonate treated in the cold
lissolves in considerable quantity, and the solution, when
the salt just mentioned; but if evaporated in a vacuum
osits dark green crystals containing the same proportion
er with 6 at. water.
hate and malate of ammonium deposits by spontaneous
cupric sulphate, then green acicular crystals unalterable
consisting of cupric malate and sulphate of ammonium.
[2] lvii. 273.)
m).—Both the neutral and acid salts are brown, gummy,
soluble in water and in alcohol. A solution of a ferric
not precipitated by alkalis.
The *neutral salt*, $C^{4}H^{4}Pb''O^{4}.3H^{2}O$, is obtained by preci-
ead with a solution of calcic or potassic malate; it is a

white curdy precipitate, which, when left for some hours converted into four-sided needles grouped around a com in boiling water to a transparent pitchy mass; it is very soluble in boiling water; a strong aqueous solution depo dissolves very easily in nitric acid; acetic acid and malic freely than pure water. Acetate of lead also dissolves slow evaporation in silky needles.

According to R. Otto (Ann. Ch. Pharm. cxxviii. 17 having, after drying at 100°, the composition $C^4H^4Pb''O^4$ a partly neutralised solution of malic acid into an exces of basic acetate of lead, boiling for several hours with d by decantation.

Both the active and inactive malates of lead melt water; the only difference observed between the two mo salt takes a longer time than the active salt to become amorphous at the time of precipitation, being conver tals in a few hours, whereas the inactive salt may days. This character may serve to distinguish between quantities of them are at hand. Both salts melt imm boiling water, but a portion dissolves and is precipitate left at rest; the active malate is then deposited afte grouped in tufts; the inactive salt, on the contrary, i state, and covers uniformly the sides of the vessel; bu phous precipitate disappears, and is replaced by needle in tufts, and exactly resembling those of the active mal

Malate of lead in the amorphous state easily parts wi water (14 per cent. = 3 at.) when dried over sulphuric a the water is retained with greater force, and it must be drate it.

Neutral malate of lead, which melts easily when throv melt in the hot air chamber, either at 100° or at a retains its crystalline aspect up to 170°, in spite of the tion, and only then begins to assume a dull woolly aspe gives off more water, and is converted into fumarate of l

β. A *basic salt*, $Pb''O.2C^4H^4Pb''O^4$, is obtained by d ammonia, or by pouring acetate of lead into the solu ammonia, or, according to Otto (*loc. cit.*), by dropping of malic acid into excess of a boiling solution of bas becomes crystalline, and does not melt in boiling water, melts, with considerable diminution of volume, being th neutral salt.

Basic malate of lead dissolves in acetate of lead, like tion, if somewhat concentrated, is precipitated by ammo water, either cold or boiling; but sufficiently soluble to few moist fragments are placed upon it.

Malates of Lithium.—Both the neutral and acid s

Malates of Magnesium.—*α. Neutral salt*, C^4H^4M of malic acid boiled with magnesia yields a liquid which, deposits after some time, rhomboïdal prisms of this sa of which are given off at 100°. Alcohol added to the co it in anhydrous flocks, which become pasty by heat.

β. The *acid salt*, $C^8H^{10}Mg''O^{10}.4H^2O$, is obtained in fl ing malic acid with carbonate of magnesium, and evap gives off half its water at 100°, and melts at a higher t

Malates of Manganese.—*α.* The *neutral salt*, whi soluble, is obtained by saturating the acid with carbons *salt* is precipitated as a white powder, on adding malic a ing salt. It dissolves in 41 pts. of cold water, and is d transparent rose-coloured crystals.

Malates of Mercury.—These salts have not been digested with *mercurous oxide*, a crystalline powder i obtained on mixing malate of potassium with a dilute s It is decomposed by boiling with water.

When *mercuric oxide* is boiled with a strong soluti

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ls of an acid salt soluble in water ; with excess of mercuric asic salt is formed. (Harff, Arch. Pharm. [3]v. 281.)

.—*α. Neutral.* Uncrystallisable, deliquescent, insoluble in t).— *β. Acid.* Crystals, permanent in the air, soluble in (Donovan.)

$^{4}Ag^{2}O^{5}$.—Nitrate of silver forms, with a solution of neutral , a white granular precipitate, which becomes yellow when d after drying, it melts and decomposes, swelling up a little, odour, and leaving perfectly white metallic silver. The t been obtained.

The *neutral salt* is uncrystallisable. The *acid salt* is crystal- soluble in water, insoluble in alcohol.

ım. *α. Neutral salt,* $C^{4}H^{4}Sr''O^{5}.H^{2}O$ (at 100°).—Malic by strontia-water; but, on evaporating the mixture, a crys- y soluble in water. When malic acid is digested with car- on is obtained which slightly reddens turmeric, and deposits lated groups of crystals having the above composition. tated in the crystalline state on adding malic acid to an eutral salt ; it is but slightly soluble in cold water, more

crystallises with difficulty; it is deliquescent, and melts .)

llow ; sparingly soluble in water. (Richter.)

-1. When an aqueous solution of malic acid is poured upon f the resulting salt dissolves, and is obtained by evapora- .—2. Neutral alkaline malates throw down from yttrium- f the two salts are concentrated and mixed in due propor- alline powder, which remains in white granules when its ated.—The air-dried salt is $C^{4}H^{4}Y''O^{5}.H^{2}O$. It does not nd is but slowly decomposed at higher temperatures. It ; its solution in aqueous malic acid deposits the neutral es abundantly in aqueous malate of sodium, and does not (Berlin.)

Neutral salt, $C^{4}H^{4}Zn''O^{5}.3H^{2}O$.—When the aqueous acid is zinc at a temperature below 30°, the filtrate deposits, after als which gradually but completely give off their 3 at. water on the other hand, the acid is saturated at a high tempera- d from a basic salt which separates on cooling, and further osited, containing indeed 3 at. water, but having a different ing about $\frac{3}{4}$ at. water at 100° (Hagen). They are short -sided prisms (square, according to Lassaigne), perpendi- d with two faces; they redden litmus (Braconnot). They ng off 10 p. c. of water, and at 120° swell up and crumble ff at the same time 10 p. c. more water (Liebig). They at 20°, according to Lassaigne) of cold, and 10 pts. h the salt does not separate on cooling. (Braconnot.)

$^{5}.4H^{2}O$.—Obtained by supersaturating the salt *α* with the ing crystals with alcohol. It forms elongated square-based when heated, giving off 8·33 per cent. water, and are con- solve in 23 pts. of cold water. (Braconnot.)

$Zn''O^{5}.4H^{2}O$?—This salt remains, on dissolving the neutral residue, containing 48·11 per cent. zinc-oxide (Braconnot). ntinuous boiling of the aqueous acid with carbonate of zinc, mulous jelly, which by prolonged boiling with water is con- r. This powder is not decomposed by water at 100°, but nd is partially converted into fumarate of zinc. (Hagen.)

$H^{3}BrO^{5}$.—No substitution-products have yet been obtained n an aqueous solution of dibromosuccinate of sodium is , a mass of crystals is obtained, having the composition of dium, $C^{4}H^{4}BrNaO^{5}$. From this salt, other bromomalates ecomposition ; but the acid itself has not yet been obtained. lium is distinguished from the bromomaleate (p. 787) and rtrate of calcium when boiled with lime-water. (Kekulé,

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Isomalic acid, $C^4H^6O^5$.

An acid, isomeric with malic acid, and perhaps id
(ii. 912), the silver-salt of which was deposited fro
containing nitrate of silver and milk-sugar, which had b
dipping papers soaked in succinic or citric acid. The fre
acid from the silver-salt, forms a crystalline mass, or
parent, well-developed crystals resembling those of au
salt, $C^4H^4(NH^4)O^5.2H^2O$, remains, on evaporating the ne
as a radio-crystalline mass. The *neutral potassium-salt*
in monoclinic laminæ. The *lead-salt* is a white pr
in water, and not melting or baking together in boi
$C^4H^4Ag^2O^5$, which is flocculent at first, is converted, wh
microscopic six-sided tables, which do not decompose at
iodide of ethyl, yields the *neutral ethylic ether*, $C^4H^4(C^2$
gradually decomposed by water.

The isomalates, treated with pentachloride of phospho
with chloride of fumaryl, according to the equation:

$$C^4H^6M^2O^5 + 3PCl^5 = 2MCl + 2HCl + 3$$

This chloride is a liquid, which is partly decomposed b
with water, is resolved into hydrochloric acid and isoma
(Kämmerer, J. pr. Chem. lxxxviii. 321.)

MALIC ACID, AMIDES OF. When ammonia
solution of ethylic malate, small crystals of malamide
$C^4H^4(C^2H^5)^2O^5 + 2NH^3 = C^4H^8N^2O$
Malate of ethyl. Malamide.
and when dry ethylic malate is saturated with ammonia-g
to a crystalline mass of ethylic malamate or m
$\left.\begin{matrix}H\\(C^4H^3O^2)'''\\C^2H^5.H^2\end{matrix}\right\}O^2N$, the decomposition being represented by th
$$C^4H^4(C^2H^5)^2O^5 + NH^3 = C^8H^{11}NO^6$$
This latter compound, dissolved in alcohol and saturated
malamide.

Malamide crystallises, by slow evaporation, in well-def
the metameric compound asparagine (i. 421) by its cryst
any water of crystallisation, and by its property of easil
thereby converted into ammonia and malic acid. It di
power: $[\alpha] = -47{\cdot}5$. (Demondesir, Ann. Ch. Phar
Malamic acid, $C^4H^7NO^4$, which is metameric with a
been isolated.

If malic acid be regarded as triatomic and dibasic, an
$\left.\begin{matrix}H\\C^4H^3O^2\\H^2\end{matrix}\right\}O^3$ (p. 790), in which two out of the three typic
that is, easily replaceable by metals, and the third, *alco*
placeable by acid-radicles (see ii. 915), the difference betw
mide on the one hand, and aspartic acid and asparagine on
by formulæ analogous to those of glycollic monamide
ii. 908) and glycocine (ii. 902), thus:

$\left.\begin{matrix}H\\(C^4H^3O^2)'''\\H^2\end{matrix}\right\}O^3$ Malic acid.

$\left.\begin{matrix}H^2\\(C^4H^3O^2)'''\\H^2\end{matrix}\right\}NO^2$ Aspartic acid.

$\left.\begin{matrix}H\\(C^4H^3O^2)'''\\H.H^2\end{matrix}\right\}ONO$ Malamic acid.

Aspartic acid bears the same relation to malic acid tha
acid. The saline or basic hydrogen of malic acid is still
the alcoholic water-residue HO of the malic acid is rep
ammonia-residue NH^2. Asparagine is the amide of aspa
aspartic acid is not decomposed by boiling with alkalis (t
in the saline place), and that asparagine, when treated in
half its nitrogen as ammonia, and is converted into aspart

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nia-residue occupies the saline place; and, consequently, amide, is boiled with alkalis, the decomposition does not amic acid, but goes on to the formation of malic acid and

$$\left.\begin{matrix} H^2 \\ (C^4H^3O^2)''' \\ H^2.H^2 \end{matrix}\right\} N^3$$

ide) of malic acid, is not known.

ide may be derived from the acid and neutral malates of f 1 and 2 at. water respectively, and, by further abstraction ds in the following table may be conceived to be formed, z. fumarimide (ii. 746), has actually been obtained:

$$\left.\begin{matrix} H \\ H^3O^2)''' \\ H^2 \\ H^2 \end{matrix}\right\} \begin{matrix} O \\ N^2 \end{matrix}$$

Malamide.

$$\left.\begin{matrix} H \\ (C^4H^3O^2)''' \\ H^2 \end{matrix}\right\} N^2$$

(unknown.)

$$\left.\begin{matrix} H \\ (C^4H^3O)_v \end{matrix}\right\} N^2$$

Nitrile (unknown).

$$\left.\begin{matrix} H \\ H^3O^2)''' \\ H^2 \end{matrix}\right\} \begin{matrix} O^2 \\ N \end{matrix}$$

lamic acid.

$$\left.\begin{matrix} H \\ (C^4H^3O^2)''' \\ H \end{matrix}\right\} \begin{matrix} O \\ N \end{matrix}$$

Malimide (unknown).

$$(C^4H^3O^2)'''.N$$

Nitrile (Fumarimide).

egarded as diatomic as well as dibasic, being represented ^{2}, which agrees perfectly with the constitution of its salts.

alamic acid and malamide are easily derived from it; but le cannot be supposed to contain the same radicle, but must imide of fumaric acid; thus:

$$\left.\begin{matrix} (C^4H^4O^3)'' \\ H^2 \\ H^2 \end{matrix}\right\} N^2$$

Malamide and asparagine.

$$\left.\begin{matrix} H^2 \\ (C^4H^4O^3)'' \\ H \end{matrix}\right\} \begin{matrix} N \\ O \end{matrix}$$

Malamic acid and aspartic acid.

$$\left.\begin{matrix} (C^4H^2O^2) \\ H \end{matrix}\right\} N$$

Fumarimide.

compound by heating acid malate of ammonium to 160°— inactive aspartic acid by boiling with strong hydrochloric ely related to malic acid, and, therefore, that the triatomic renders it possible to express fumarimide by a formula as the acid, must be regarded as preferable (Kekulé). lic acid to succinic and tartaric acids cannot be adequately nula.

bling fumarimide or malonitrile, are likewise obtained, the action of heat on acid fumarate and acid maleate of

NYLATED AMIDES OF. These compounds have d than the primary amides of malic acid; three of them e (Ann. Ch. Pharm. xcvi. 106), viz. diphenyl-malamide, l-malamic acid.

Malanilide. $C^{16}H^{16}N^2O^3 = \left\{\begin{matrix} H \\ (C^4H^3O^2)''' \\ (C^6H^5)^2.H \end{matrix}\right\} \begin{matrix} O \\ N^2 \end{matrix}$.—This com-

th phenyl-malimide, by melting malic acid with aniline:

$$C^4H^6O^5 - 2H^2O = C^{16}H^{16}N^2O^3.$$

Malic acid. — Diphenyl-malamide.

$$C^4H^6O^5 - 2H^2O = C^{10}H^9NO^3$$

Phenyl-malimide.

l times with boiling water, is resolved into a nearly colour- nyl-malimide, and a strongly coloured residue consisting e, which may be obtained pure and colourless by crystal- , with the aid of animal charcoal.

having a faint lustre; melts, with partial decomposition, perature volatilises for the most part unaltered. When set t smoky flame.

ater, and in dilute *hydrochloric acid*, *ammonia*, and *potash*. gly in *alcohol* and *ether*. Strong *sulphuric acid* dissolves *ric acid* dissolves it in the cold, forming a yellow solution.

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When boiled with strong caustic *potash*, it dissolves an
posed, a fatty substance rising to the surface of the lic
the semifluid portion is converted into a white insol
completely freed from potash by washing with water.
some difficulty in alcohol, and crystallises therefrom in
needles. It may be heated, without visible alteration
temperature; and if cautiously heated, yields a crystalline
a small quantity of charcoal. This substance gives by a
and 5·41 hydrogen: hence it appears to be *tartranilide*.

$$C^{16}H^{16}N^2O^4 = 2C^6H^7N + C^4H^4O^4$$

Phenyl-malimide. Malanil. $C^{10}H^9NO^2 = (C^4H$

with the preceding compound, by melting a mixture of
the fused mixture is kept in a state of gentle ebullition
syrup is obtained, which solidifies on cooling, and whe
nearly colourless solution of phenyl-malimide, and a
diphenyl-malamide. The solution when evaporated y
form of a granular mass, still, however, mixed with diph
is purified by digestion in hot water, and filtration.
purified by treatment with animal charcoal, and evapora

From a hot concentrated aqueous solution, phenyl-ma
delicate needles grouped together; also when its alco
sometimes, however, it forms nacreous laminæ, and from
it is deposited in very thin, iridescent, rectangular prism
heated between two watch-glasses, forms a slight mealy
abundantly in *water*, *alcohol*, and *ether*.

Phenyl-malimide, boiled with aqueous *ammonia*, is co
of ammonium.

It dissolves easily in the strongest *nitric acid*, formi
which water throws down a nearly colourless, indistinc
nitro-phenyl-malimide, accompanied by a resinous b
separate. The crystalline body dissolves easily in boil
cooling yields fine needles. (Arppe.)

Phenyl-malamic acid. Malanilic acid. $C^{10}H$

acid is obtained in the form of an ammonium-salt by
aqueous ammonia (*vid. sup.*). The solution of this salt fo
cipitate, which, when mixed with a small quantity of wa
aid of heat, by an exactly equivalent quantity of sulphu
acid; and from the solution, filtered while yet warm, t
and may be purified by recrystallisation from alcohol.
phuric acid used in the preparation converts the phen
malimide; hence it is best to use rather less than the e

The acid crystallises in white, faintly lustrous granu
needles, and scarcely attaining the size of a pin's head
sour taste, reddens litmus, and decomposes carbonate
somewhat less in *alcohol*, and sparingly in *ether*. Its s
their solubility in water.

The solution of the ammonium-salt remains clear wh
is slightly clouded by boiling with *potash*; with *acetate*
cipitate soluble in water; and with *sesquichloride of iro*
colour.

The *barium-salt* is very soluble in water, and crystal
dazzling whiteness; it is insoluble in hydrochlorate of
Phenyl-malamate of silver, $C^{10}H^{10}AgNO^4$, forms a
becomes coloured by exposure to light; it dissolves in w
solution in shining cubes.

MALIC ETHERS. These compounds have not
to Demondesir (Compt. rend. xxiii. 227), the malate
duced by passing hydrochloric acid gas into a soluti
wood-spirit. The neutral ethers cannot be distilled; th
the crude liquid with carbonate of sodium and agitati
takes up the ethylic or methylic malate, and leaves it

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ined still contains water and alcohol or wood-spirit, which
ration in a vacuum.

ethyl and methyl are liquids which are soluble in water,
osed by distillation, being converted into the corresponding
nverted into malamide by ammonia. They possess optical

malic acids are always formed by the above process simul-
ethers. Their calcium-salts are soluble in alcohol.
$C^4H^5(C^3H^{11})O^5$, is obtained by prolonged heating of malic
o 120°. It forms a syrup which crystallises on cooling.

th Oil of Apples (i. 532; ii. 636).

$C^3H^4O^4 = \left.\begin{matrix}(C^3H^2O^2)''\\H^2\end{matrix}\right\}O^2$. An acid discovered by Des-
m. cvii. 251), who obtained it by slowly oxidising malic
f chromate of potassium:

$$\underset{\text{lic}}{C^4O^5} + O^2 = CO^2 + H^2O + \underset{\text{Malonic acid.}}{C^3H^4O^4}.$$

volution of ammonia, by the action of alkalis on cyanacetic
ic ether:

$$\underset{\text{anacetic acid.}}{C^3(CN)O^2} + 2H^2O = NH^3 + \underset{\text{Malonic acid.}}{C^3H^4O^4}$$

$$\underset{\text{tic ether.}}{(C^2H^5)O^2} + 3H^2O = NH^3 + \underset{\text{Alcohol.}}{C^2H^6O} + \underset{\text{Malonic acid.}}{C^3H^4O^4}$$

boiling cyanacetic ether* with potash, forms with sulphate of
which by decomposition with sulphydric acid, and evaporation
nic acid. (Hugo Müller, Chem. Soc. J. xvii. 109.)
ge rhombohedral crystals, having a laminar structure. It
d *alcohol*, melts at 140°, and decomposes at 150° into carbonic

been but little examined. The *neutral potassium-* and *am-*
ent and crystallise with difficulty; the *acid salts* of the same
The *barium-* and *calcium-salts* are crystalline precipitates
vater. The *silver-salt* is insoluble and crystalline; the *lead-*

c acid, obtained by Barral (Compt. rend. xxi. 1374) from
ion of malonic acid, and is probably identical therewith. It
s, forms insoluble lead- and silver-salts, and is resolved by
ide and acetic acid.

fly barley, which has become sweet from the conversion of
n incipient growth or germination artificially induced, called
27; also *Ure's Dict. of Arts*, &c. iii. 18)

neral tallow of Kirwan, said to have been found on the coast
es wax. Its specific gravity is 0·77. It is white, brittle,
lts with a moderate heat, and burns with a blue flame and
s readily in oil, and imperfectly in hot alcohol.

See Montmorillonite.

name is given by Dubrunfaut (Ann. Ch. Phys. [3] xxi.
ced from starch-paste by the action of malt or diastase.
se in crystalline form and most other respects, but its dextro-
ng to Dubrunfaut, three times as great as that of dextro-glu-
a recently prepared solution than after the lapse of several
rs also to be less easily altered by alkalis. It is converted
ling with dilute sulphuric acid.

brown mineral from Mancino, near Leghorn, consisting, ac-
n. Min. [3] xix. 703), of sesquisilicate of zinc, $2ZnO.3SiO^2$.
with two unequal cleavages inclined to one another at 92°.

. *Formo-benzoilic acid*, $C^{16}H^{16}O^6$.—This acid, which con-

btained by the action of chloracetic ether on cyanide of potassium, or of
lver.

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tains the elements of bitter almond oil and formic ac
+ $2CH^2O^2$, and is related to benzoic acid (so far at least as
in the same manner as lactic to acetic acid, was discovered
Pharm. xviii. 310), who obtained it by heating bitter almon
acid, the hydrocyanic acid contained in the liquid being th
and formic acid, which, at the moment of its formation, uni
oil (Liebig, Ann. Ch. Pharm. xviii. 39). It is also p
fuming sulphuric acid on bitter almond oil (Laurent,
202), and by heating amygdalin with fuming hydrochloric a
Pharm. lxvi. 238.)

Preparation.—Bitter almond water—obtained by distilli
paste with 90 lbs. of water till 160 oz. have passed over,
liquid, and shaking up the distillate with the bitter almond
hydrochloric acid of specific gravity 1·12, and evaporated t
bath, till all the hydrochloric acid is expelled. The yel
smelling slightly of bitter almonds, leaves pure sal-ammonia
ether; and the ethereal solution yields by spontaneous eva
crystalline mass, which, when treated with water, leaves
having the odour of bitter almonds. The aqueous solution
less, and contains pure mandelic acid, which crystallises on
—2. When bitter almond oil is treated with one-third of
phuric acid, heat is evolved, the liquid becomes brown an
compact mass on cooling. The mass, when treated with wa
solid layer containing undecomposed bitter almond oil and
layer containing mandelic acid and excess of sulphuric aci
tallises from the latter on cooling (Laurent).—3. A so
hydrochloric acid is evaporated over the water-bath, and the
ether, which dissolves the mandelic acid. On evaporating
acid crystallises. (Wöhler, Liebig.)

Properties.—Mandelic acid forms a scaly crystalline mas
tallises sometimes in rhombic needles, sometimes in rho
having their acute angles truncated (Laurent); in plates
system (J. Heusser, Pogg. Ann. xciv. 637). It has a
almonds, and a strong acid taste, with a somewhat styptic a
with loss of water, into a yellow oil, which, on cooling, solid
(Winckler). When a solution of mandelic acid in stron
porated at a temperature above 100°, it becomes amorpho
solution with a small quantity of water, but is precipitated
form of a heavy yellowish oil (Wöhler). The acid is very
and *ether*.

Decompositions. The acid, *heated* above its melting p
odour, recalling those of white-thorn blossoms, hyacinth, a
in a distillatory apparatus to a temperature short of carboni
a dark brown, resinous, balsamic mass, which dissolves spar
in alkalis and in alcohol. A large quantity of bitter alm
same time. The acid burns with a red, smoky flame, leavin
tible charcoal (Winckler). When it is boiled with *nitri*
fumes continue to escape, the formic acid is decomposed,
is converted into benzoic acid, which crystallises on addit
When *chlorine gas* is passed through an aqueous solutio
smelling like chloride of benzoyl separates at first; and if
the passage of the chlorine continued till this oil has comple
tion, when subsequently treated with acid, gives off carboni
benzoic acid in the form of a crystalline magma (Liebig).
of vitriol, and the solution, when gently heated, gives off
The aqueous solution, boiled with *peroxide of manganese*,
and bitter almond oil. (Liebig.)

Mandelates.—The acid neutralises bases completely,
from its compounds. (Winckler.)

Mandelate of Ammonium.—This salt is obtained by sli
aqueous acid with ammonia, and leaving the solution to eva
to crystallise, and generally forms a yellowish-white mass.
When heated, it decomposes in the same manner as the free
smallest quantity of water, and readily in alcohol. (Winc

Mandelate of Barium, obtained by decomposing carbonate
acid, crystallises readily in small, tolerably hard needles.
in water than the potassium-salt. (Winckler.)

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solution of sulphate of copper, precipitated by mandelate ight-blue powder, which, when heated, gives off a large il.

cipitated as a white, finely crystalline powder, on adding neutral acetate of lead. When heated, it behaves like the soluble in water. (Winckler.)

crystallises readily. (Winckler.)

tained by precipitating mercuric nitrate with mandelate of losely resemble those of the copper-salt. (Winckler.)

—Obtained by nearly neutralising carbonate of potassium orating to dryness, exhausting the dry mass with alcohol, solution to evaporate. It is a white, soft, easily friable, mild, scarcely saline taste, faintly resembling that of sweet ke the free acid when heated, takes fire easily and burns pure carbonate of potassium. It dissolves very readily in kler.)

ined by precipitating nitrate of silver with neutral mande- white, heavy, crystalline powder, easy to wash. From its the boiling heat, it separates in rather hard crystals having t melts at a somewhat high temperature into a dark mass, acts of decomposition as the acid, leaving metallic silver.

OLE. See RHODONITE.

onymes. *Manganese, Mangan, Mangadium.* Symbol, Mn;

manganese, a substance long used to decolorise glass, and s resemblance to the loadstone, was formerly included among wever, proved by the researches of Pott in 1740, of Kaim Scheele and Bergmann in 1774, that the metal contained om iron, and possesses characters peculiar to itself. The ated by Gahn. Chevillot and Edwards, in 1818, pointed - a substance discovered some considerable time before— f manganese. Forchhammer, in 1820, distinguished two itscherlich, in 1832, fully confirmed the distinction.

in the form of peroxide, known as black oxide of manga- manganoso-manganic oxide; as sulphide, carbonate, sili- uantities also, as colouring matter in many siliceous minerals in the ashes of plants and in the bones of animals.

—1. Hydrogen and charcoal at a red heat reduce the supe- protoxide, but do not eliminate the metal; but at a white netal of the whole of its oxygen. The following process, *ehlen's Journal für Chemie und Physik*, iii. 452), is com- n of manganese. A finely-divided oxide of manganese, rbonate in a well-closed vessel, is mixed with oil and ignited to convert the oil into charcoal. After several repetitions naceous mass is reduced to powder, and made into a firm little oil. Finally this paste is introduced into a crucible *rasqué*, p. 388), the unoccupied portion of which is filled up crucible is first heated merely to redness for half an hour, to the oil, after which its cover is carefully luted down, and d a half to the most violent heat of an air-furnace that the ithout undergoing fusion. The metal is obtained in the s or button in the lower part of the crucible, but not quite carbon and silicium derived from the ashes of the charcoal. nd time in a charcoal crucible, with a portion of borax, le and brilliant, and so free from carbon that it left no d in an acid.

. Pharm. cii. 330; Jahresb. 1857, p. 201) obtains manga- e or fluoride with sodium, in a manner similar to Deville's f aluminium: *a.* 2 pts. fluoride of manganese, and 1 pt. rnate thin layers in a hessian crucible; the mixture is well hloride of sodium; and over the whole is placed a layer of to prevent spirting). The crucible, with the cover on, is ce, first gently, then, when the commencement of the action ise, to bright redness for a quarter of an hour, after which, ace are closed, and the whole is left to cool. If the heat

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has been strong enough, the manganese is found in a f
crucible; if not, it must be heated again under a layer
sium, mixed with $\frac{1}{10}$ of nitre (borax attacks it too stron

β. Instead of fluoride of manganese, a mixture of eq
nese and finely-pulverised fluor-spar may be used, an
manner above described.

Manganese may be obtained in the pulverulent state
in a tube filled with vapour of rock-oil. (Giles.)

Properties.—Manganese, obtained by reduction of ei
is a greyish-white metal having the aspect of cast iro
fine-grained structure, and is easily split. Specific g
magnetic. Melts only at the strongest heat of a blas
when exposed to the air, and must, therefore, be kept u
It decomposes water slowly at ordinary temperatures,
tion of hydrogen, in hydrochloric or dilute sulphuric
simple metallic salts, except the salts of silver and go
is very slight.

The metal obtained from the chloride or fluoride by
aspect of cast iron, and is very brittle, but it is not m
in testing it]; has a specific gravity of only 7·138 to 7·
and cut glass like a diamond; may be polished; and
air, at ordinary temperatures; when heated on platinu
steel, and covered with a brown film of oxide. Und
ordinary temperatures, more quickly at the boiling
evolution of hydrogen. When immersed in strong su
small quantity of hydrogen at ordinary temperatures,
evolution of sulphurous anhydride. In dilute sulphuri
at ordinary temperatures; also in nitric acid, in very
acetic acid.

H. Deville (Compt. rend. xliv. 673) attributes the
nese prepared by Brunner's method, and that obtained
with charcoal, to the presence, in the former, of impu
adhering to the sodium, and to silicium from the fluo
that Brunner's manganese, when dissolved in hydroch
able residue of hydrated oxide of silicium; and Bru
that this residue, from 12 samples obtained in differen
to 6·8 per cent. By fusing the coarsely-pulverised m
chloride of sodium containing 1 per cent. of chlorate
silicium could be reduced to 0·1 per cent.; but Brunner
in the proportion of the silicium made any difference i
or lustre of the metal. (See MANGANESE, SILICIDE OF.)

Manganese enters as a base into two classes of compo
compounds, in which it is bivalent, and the manga
trivalent. It likewise enters as an acid-radicle into tw
nates and permanganates. Examples of these comp
table:—

Manganous chloride . .	$MnCl^2$ = 55
Manganous oxide . . .	MnO = 55
Manganic chloride . . .	Mn^2Cl^6 = 2 . 55
Manganic oxide . . .	Mn^2O^3 = 2 . 55
Manganate of potassium	MnK^2O^4 = 55
Permanganate of potassium	$Mn^2K^2O^8$ = 2 . 55

Manganese also combines with chlorous elements
peroxide = MnO^2.

MANGANESE, ALLOYS OF. The compou
metals are not of much importance. It unites with co
iron (iii. 368), and gold, forming white, brittle, and
An alloy of manganese and aluminium, $MnAl^2$, i
10 pts. anhydrous chloride of manganese, 30 pts. of
potassium and sodium in atomic proportions, and 15 p
resulting regulus with dilute hydrochloric acid. It
powder, of specific gravity 3·402, insoluble in cold, b

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ncentrated hydrochloric acid; it is decomposed by caustic
e aluminium dissolving out. (Wöhler, Ann. Ch. Pharm.

se is obtained by reducing a solution of the chloride with
Phil. Mag. [4] xxiv. 328.)

ENIDE OF. Mn^2As^2.—This compound occurs as a
anganese or *Kaneite*, in botryoïdal masses, or amorphous
ructure. Specific gravity 5·55. Hard. Greyish-white.
ckish-grey powder when exposed to the air. Melts on
with the platinum. Before the blowpipe, it burns with a
d emission of white fumes of arsenious anhydride. It
nuriatic acid, and in a large quantity of nitric acid. Con-
nalysis (Pogg. Ann. xix. 145), 45·5 per cent. manganese,
manganese (= 97·3), the formula requiring 42·75 Mn and
mined was supposed to be from Saxony.

IDE OF. $MnBr^2$.—The anhydrous bromide is obtained
y heating the pulverised metal in bromine-vapour. By
ydrobromic acid and evaporating, the hydrated bromide,
small, red, deliquescent needles, isomorphous with the
nganous chloride (Marignac, see p. 804). The crystals,
close vessel, give off their water of crystallisation, and
; and this, when ignited in contact with the air, gives
ves manganoso-manganic oxide. It is decomposed by
oing off partly in the free state, partly as hydrobromic

RIDES OF.—*α. Manganous Chloride*, $MnCl^2$.
by direct combination, the finely-divided metal taking
ine gas. It is also produced by passing dry hydro-
nous carbonate or the red oxide, heated first gently,
the process being continued till the gas is no longer
orms a clear, colourless liquid. The air must be care-
hole of the reaction; the mass must be left to cool in
cid; and the excess of the latter finally expelled by a

ed by this process, or by heating the hydrated chloride,
, having a lamino-crystalline structure. According to
n yellow crystals, by passing chlorine gas over a strongly
s oxide and charcoal; also, by exposing a mixture of the
a gradually increasing heat. Manganous chloride melts
heat, but does not volatilise at a temperature above the
not decomposed by heat alone, if air be excluded, but
gives off hydrochloric acid, and leaves manganoso-man-
does not act upon it at a red heat, but *phosphoretted*
ng phosphide of manganese and hydrochloric acid. When
tly converted into sulphide of manganese. When *water*
chloride, it becomes hot, and dissolves very easily. It is

$4H^2O$.—The protoxide and carbonate of manganese
ochloric acid; and the higher oxides, with evolution of
ith, the product being in all cases manganous chloride.
ferric chloride and other substances, in the waste-liquor
by heating the common black oxide of manganese with
liquid accumulates very quickly in chemical laboratories,
tion, be advantageously used as a source of the pure
other preparations of manganese. The iron, which is
removed by boiling down considerably, to expel the
luting with water, and boiling again with carbonate of
pitates the whole of the sesquioxide of iron, forming
its acid. If about one-fourth of the impure solution
reserved, and precipitated by carbonate of sodium, a
ganese will be obtained, which is sufficient to precipitate
fourths of the liquid, and may be used for that purpose
The iron may likewise be separated by evaporating the
de to dryness, heating the residue to low redness in a

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crucible, as long as hydrochloric acid continues to escap
hausting with boiling water, and filtering. The hydrat
by the heat into hydrochloric acid and sesquioxide, wh
remains unaltered, and is easily dissolved out by water,
(Everitt, Phil. Mag. [3] vi. 493). Chloride of mangan
cipitated white, without any shade of blue, by ferrocyani
flesh-red colour, by sulphide of ammonium: the latter
slightest trace of iron imparting a perceptible blackness
By precipitating the whole of the solution with sulphide
may be freed from barium, calcium, and other impurities
it must be removed by sulphydric acid, before precipitati

The solution of chloride of manganese, obtained by e
by cooling, or by spontaneous evaporation, between 15° a
chloride having the composition above indicated. They
minations of their form by different observes do
Schabus (*Beschreibung der Krystallgestalten*, &c.),
∞P . [$\infty P\infty$] . [$P\infty$]. Ratio of clinodiagonal, ortho
= 0·4101 : 1 : 0·8331. Angle of inclined axes = 54°
diagonal principal section = 142° 56′; [$P\infty$] : [$P\infty$]
to Rammelsberg (*Krystallographische Chemie*, p. 45
sur les formes crystallins de quelques composés chimi
rend. xlii. 288), the clinod., orthod., and principal
1·1525 : 1 : 0·6445, and the angle of the inclined axes
in the clinodiagonal principal section = 82° 40′;
$\infty P\infty$: [$P\infty$] = 97° 15′.—Marignac has since found
crystals of the same composition, but of different for
hydrated ferrous chloride, $FeCl^2.4H^2O$, are sometimes
manganous chloride, supersaturated by evaporation at
stand for some time at a temperature between 0 and + 6
lous paper. These crystals are also monoclinic, but the
69° 14′. They exhibit the combination 0P . + P . − P
the clinodiagonal principal section = 86° 0′; − P : − P
− P in the orthodiagonal principal section = 103° 5
− P = 126° 30′; oP : [$\frac{1}{2}P\infty$] = 142° 30′. Hydrated m
dimorphous. It must be observed, however, that the
rare occurrence, the solution, even when evaporated unc
just mentioned, generally yielding the ordinary crystals
to the determinations of Marignac and Rammelsberg.
Schabus are decidedly different from both, it is probabl
hydrate.

The crystals ($MnCl^2.4H^2O$) placed over oil of vit
receiver containing air, lose 2 at. water at ordinary temp
they become white and opaque (John); between 25°
scopic water with decrepitation, and become hard; at
50° semi-fluid; and at 87·5 they form a mobile liquid,
mass be kept for some time at a temperature near 100°,
of water, and leaves a white powder, which retains 1 at.

Both the anhydrous and the hydrated chloride del
part of the crystals absorbing 1·2 parts of water. On
dissolves at 10° in 0·66 parts; at 31·25° in 0·37; and at
in 0·16 parts of water (Brandes). The solution has
syrupy consistence.

The salt dissolves readily in alcohol, but is insoluble i
The alcoholic solution of the hydrated salt is green, an
crystals, still containing 4 at. water. The anhydrous ch
in boiling absolute alcohol, crystallises out on cooling, an
porated in vacuo yields an additional quantity of cry
weight of alcohol.

A solution of manganous chloride is not altered by pa
if chloride of potassium, chloride of barium, &c., be add
tate of hydrated peroxide of manganese is formed (S
Phys. [3] xxxix. 161). According to Millon (Jahre
oxidation is produced by chlorine water which has b
therefore contains hydrochloric and hypochlorous acids.

Manganous chloride forms two crystalline double salt
One of these, $MnCl^2.2NH^4Cl$, forms cubical crystals cont
Rammelsberg, and 2 at. according to v. Hauer. The cry

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in microscopic pyramids resembling hausmannite. The other $^{4}Cl.2H^{2}O$, forms monoclinic crystals (Hautz). Solution of taining chloride of ammonium yields, on addition of ammonia air, a precipitate of hydrated manganoso-manganic oxide.

anous chloride and mercuric cyanide, $MnCl^{2}.2HgCy^{2}.6H^{2}O$, is s evaporation of a solution containing the two salts in atomic four-sided prisms, which effloresce quickly in the air, and are (Poggiale.)

ride, $Mn^{2}Cl^{6}$, is not known in the solid state, but when finely ganic or manganic oxide is added by small portions at a time, temperature, to cold concentrated aqueous hydrochloric acid, ed, which slowly becomes colourless at ordinary temperatures, heated or exposed to sunshine—chlorine being evolved and luced: hence the solution dissolves metals as readily as chlorine- erts sulphurous and sulphydric acids into sulphuric, and tartaric addition of water in large quantities precipitates manganic the formation of manganous chloride. (Forchhammer.)

ed into a solution of 1 pt. manganous chloride in 19 pts. water l gradually solidifies to a yellow crystalline mass which, how- t part, on slight rise of temperature (John). The crystals very readily in the air, and are decomposed by gentle heating, manganous oxide in hydrochloric acid.

Manganese, $Mn^{2}Cl^{14}$? When sulphuric acid is added to a green ganate till the liquid turns red; the solution then evaporated to nsisting of sulphate and permanganate of potassium, dissolved ; the solution introduced into a tubulated retort; and fragments m added as long as coloured vapours are evolved,—the copper- rs which distil over, condense entirely in a tube attached to the to − 15° or − 20°, forming a greenish-brown liquid. The n contact with moist air in a wide tube, produce a dense rose- on the sides of the tube, with evolution of hydrochloric acid, a permanganic acid (Dumas, Ann. Ch. Phys. [2] xxxvi. 81). npound as probably analogous to the chromate of trichloride of

YANIDES OF. See CYANIDES (ii. 253).

ETECTION AND ESTIMATION OF.—1. *Reactions* l compounds of manganese, heated with borax or phosphorus- ipe flame, form an amethyst-coloured bead containing man- which becomes colourless in the inner flame by reduction of anous oxide. This reaction, when not disguised by the pre- forming coloured beads, is extremely delicate, and serves to rom all other metals. Another reaction, equally characteristic, l not likely to be interfered with by the presence of other heating the substance under examination with two or three nate of sodium and a little nitre, on platinum-foil in the outer smallest trace of manganese will then be indicated by the ganate of sodium. The best way of applying the heat is to f the flame on the under side of the platinum-foil immediately In testing for traces of manganese in ores which are rich in hem with nitric acid, which dissolves the iron as ferric-salt; ion with carbonate of sodium, and precipitate the iron with saturate the filtrate with ammonia, add one drop of sulphide the precipitated sulphide by fusion with nitre and carbonate

lution.—a. Of Manganous Salts.—These salts have a pale estroyed by sulphurous or hydrochloric acid, and must there- aracteristic. When the solution is colourless, as is sometimes ained, according to Görgeu, by the presence of a salt of iron, green or blue tint of the latter metals producing a white or et tint, when combined with the rose colour of a manganous

s no precipitate in neutral solutions of manganous salts con- nger acids. In a neutral solution of the acetate, a flesh- formed after some time; but not if the solution contains free *f ammonium* forms, in neutral solutions of manganous salts, a

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flesh-coloured precipitate of hydrated sulphide of ma
sulphide of ammonium, but readily soluble in acids.
turns brown on the surface, from oxidation. This rea
other metal giving anything like it; a very small t
colours the precipitate black.

Caustic alkalis, added to solutions of manganous sa
of manganese in the form of a white hydrate, which
air, and becomes brown; when collected on a filter and
into a blackish-brown powder, which is the hydrate
change is instantaneously produced by the action of
hydrate, or by the addition of chloride of lime to a s
nese; but then the hydrated peroxide is formed. A
hydrate from neutral manganous solutions; in solution
niacal salts, it gives no precipitate; but if sufficient am
on exposure to the air, gradually deposits all the mang
The *alkaline monocarbonates* precipitate white carbo
not turn brown in the air, and dissolves sparingly in a
Acid carbonate of potassium precipitates a strong solut
dilute solution slightly turbid; but if the solution c
excess of carbonic acid is set free, no precipitate is fo
do not precipitate manganous salts. *Alkaline phospha*
white precipitates.

Ferrocyanide of potassium forms in neutral solution
precipitate, having a tinge of red, and soluble in free ac
forms a reddish precipitate, insoluble in acids.

The least trace of a manganous salt may be detected
little *dioxide of lead* (or red lead), and *nitric acid*, whe
is produced, owing to the formation of permanganic ac
manganic oxide. The colour is readily perceptible wh
subsided. This is the most delicate test for manganese

All compounds of manganese, after boiling with hyd
actions of manganous salts.

β. *Of Manganic salts.*—Solutions of manganic salts
a black precipitate of manganic hydrate, unless chlori
which case no precipitate is formed. They are very un
ganous salts merely by heating, also by *hydrochloric*,
any *organic compound*, the liquid then becoming colou
reduces them to manganous salts, and then precipitates

γ. *Of Manganates.*—The manganates of the alkali
forming green solutions, which, however, are very u
exposure to the air, from formation of permanganic a
hydrated peroxide; this change is retarded by the
Nitric, *sulphuric*, or *hydrochloric* acid, effects the cha
acid, the red solution gradually becomes brown, and,
to the formation of manganous chloride. The solution
rous and *sulphydric acids*, and other reducing agents.

δ. *Of Permanganates.*—The alkaline permangana
purple-red colour. They are very easily reduced by
reducing agents (e. g. *hydrochloric*, *sulphurous*, *arsenio*
ferrous salts, *stannous salts*, &c.), the solution first
colourless.

3. *Quantitative Estimation and Separatio*
cipitating manganese from the solution of a manganou
sodium at the boiling heat. The precipitated carbon
washed with boiling water, and calcined at a strong re
into manganoso-manganic oxide, Mn^3O^4, containing 72
the solution contains a considerable quantity of ammonia
after mixing it with excess of carbonate of sodium, and
of the residue by water.

From the metals of Group I. (i. 217), manganese is
tion of its sulphide from an acid solution by sulphydric
metals of Group II., which, like manganese itself, are pr
nium and not by sulphydric acid, is more difficult.

The methods of separating manganese from iron
Iron (p. 386). The best is to precipitate the iron (pr
state by succinate or benzoate of ammonium) from a sol
ammonia.

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and zinc, manganese may be separated by mixing the solu-
um, and saturating with *sulphydric acid gas*, which throws
aving the manganese in solution. In the case of cobalt and
not contain much free acid. The separation thus effected is
, but it may be rendered almost absolute by repeating the
. Other methods of separating manganese from cobalt are
046). One of the best is that which consists in converting
des, and igniting them in a stream of *hydrogen*, which reduces
chloride of manganese undecomposed. The same methods
g manganese from nickel.
anese is separated by precipitating that metal as uranic oxide
barium, which leaves all the manganese in solution. For the
im, see i. 915.
are precipitated by sulphide of ammonium from their neutral
. those of the earths proper, also cerium, lanthanum,
ese may be separated by mixing the solution with a sufficient
to prevent the precipitation of those metals by an alkali,
mmonia, and precipitating the manganese by *sulphide of am-*

rium, zirconium, cerium, lanthanum, and didy-
separated by precipitating those metals with *oxalate of*
sal-ammoniac to retain the manganese in solution; from
tals, also by sulphate of *potassium* (i. 833).
paration from titanium, tantalum, and niobium, see

d glucinum, manganese, if in small or moderate quantity
y boiling the solution with *potash* in an open vessel. The
pitated in the form of sesquioxide, while the alumina and
he potash. If, however, the proportion of manganese be con-
nnot be used, because the oxide of manganese carries down
ntities of alumina and glucina. In this case the liquid must
niac, and the alumina and glucina precipitated by *ammonia*
always contains small quantities of manganese, which must
nt treatment with potash.
rontium manganese is easily separated by means of *sulphate*
lown the barium and strontium as sulphates; also by *sulphide*
alcium and magnesium it is separated by *oxalate of*
solution be sufficiently dilute, precipitates the manganese
hide. The separation from calcium may also be effected by
onium, after the addition of chloride of ammonium to keep
n.
l from the alkali-metals by means of *carbonate of sodium*
, which latter precipitates it in the form of sulphide. The
water containing a small quantity of sulphide of ammonium;
; and the manganese precipitated from the solution by car-

es of Manganese.—As the commercial value of manganese
quantity of metal, but on that of the available oxygen con-
of assaying them does not properly come under the estimation
e best considered in connection with the oxides of manganese.

of Manganese.—The earlier determinations of this number
y, and Forchhammer, were either too high or too low.
chw. J. xlii. 202), by precipitating the solution of mangan-
e of silver, found the atomic weight of manganese to be 28,
as that of iron. Turner, in the same year (Phil. Mag. [2]
thod, obtained the number 27·49, and by determining the
ulphate produced by treating a known quantity of manganous
l, he found Mn = 27·96. Berzelius in 1830 (Pogg. Ann.
tating manganous chloride with nitrate of silver, found that
5 AgCl; whence, if Ag = 108 and Cl = 35·5, calculation gives
n 1859 (Ann. Ch. Pharm. cxiii.), found, as a mean of five
= 27·48.
ntr. 1857, p. 88) determined the atomic weight of manganese
manganous sulphate into the corresponding sulphide. The
e sulphate was thus found, as a mean of nine experiments, to
n 42·351 to 42·428); whence Mn' = 27·49.

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The most exact of the preceding experiments appear to
of manganese is 27·5 or 55, according as it is regarded a
R. Schneider (Pogg. Ann. (1859) cvii. 655) has, hov
result: 1. By determining the quantity of water produc
ganoso-manganic to manganous oxide by reduction with
the ratio between the carbon and manganese in mangano
gave as a mean, Mn′ = 27·01; the second 27·02. Schn
the true atomic weight of manganese, Mn′ = 27 or Mn″ =

MANGANESE, EARTHY. This term is appl
occurring in amorphous, loosely coherent masses (see p.

MANGANESE, FLUORIDES OF. *Manganous*
by dissolving the carbonate in excess of hydrofluoric acic
of acid, the salt separates in small, indistinct, amethys
insoluble in pure water, but dissolve in water containing
fluoride is not decomposed by heat alone, but when h
metallic manganese (p. 801).

Manganic fluoride, Mn^2F^6, is obtained by digesting the
excess of hydrofluoric acid. The resulting dark brown s
evaporation, crystals of manganic fluoride, which are
light, and yield a rose-coloured powder. They dissolv
very small quantity of water; but the solution is decomp
acid fluoride and an insoluble basic compound or oxyf
the solution, throws down manganic hydrate.

Perfluoride of Manganese, Mn^2F^{14}?—When a fused mix
hydrate of potassium, and chlorate or permanganate of
its weight of fluor-spar, and drenched with strong sulph
formed, which is decomposed and acquires a purple colo
and corrodes glass, forming fluoride of silicium and per
it is resolved into hydrofluoric and permanganic acids, for
remains unchanged in stoppered bottles, but, when ev
and hydrofluoric acid vapour, and leaves a brown shini
dissolves manganous fluoride, leaving a black insoluble
dissolves copper, mercury, and silver (not gold or platinu
the same time becoming perfectly colourless. (Wöhl
also Dumas, Ann. Ch. Phys. [2] xxxvi. 82.)

MANGANESE, GREY. A term sometimes appl
lusite (pp. 810, 811).

MANGANESE, IODIDES OF. α. *Manganous*
manganous carbonate in aqueous hydriodic acid leave
having a somewhat styptic taste. When kept from co
without decomposition; but on the admission of air, it is
and manganous oxide. It deliquesces in the air, and diss
a colourless solution, which, on evaporation, deposits
when exposed to the air, is slightly decomposed, deposi
and chlorine, as well as concentrated nitric or sulphur
(Lassaigne.)

β. *Manganic iodide.*—Very finely-pounded peroxide
cold aqueous hydriodic acid, yields a dark yellowish-red
evolves iodine, and is rapidly converted into manganous

MANGANESE, OXIDES OF. Manganese for
composition, viz.:—

Protoxide or Manganous oxide	. . . .
Manganoso-manganic oxide	. . . .
Sesquioxide or Manganic oxide	. . . .
Dioxide or Peroxide	. . . . .

The protoxide is a strong base, forming with acids a cl
sesquioxide is a weak base. Manganoso-manganic acid
composition in certain acids. The peroxide, treated with
ganous or manganic oxide and free oxygen.

There are also two or three other native oxides, interme
the sesqui- and di-oxides, viz. *Varvacite*, *Newkirkite*, &c., b
and are probably mere mixtures. Besides these it is us
oxides, MnO^3 and Mn^2O^7, which are the anhydrides cor
permanganic acid respectively: but they have not yet been
at present be regarded as merely hypothetical. (See Ma

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ganous oxide, MnO.—This oxide may be prepared by
rate, carbonate, or oxalate, at a moderate heat in a closed
eam of hydrogen, and allowing the product to cool in that
preparation is, however, that recommended by Liebig and
i. 584), which consists in mixing equal parts of fused man-
bonate of sodium with a small quantity of sal-ammoniac,
it fuses, and exhausting the fused mass with water when

greyish-green powder, which, according to Despretz, melts at
a fine green-coloured mass. By heating it to a cherry-red
with a very small quantity of hydrochloric acid gas, Deville
obtained it crystallised in transparent regular octahedrons
our, and adamantine lustre. It is not deoxidised by any
eated in sulphydric acid gas, it yields water and manganous
used with sulphur, sulphurous anhydride is evolved, and
emains behind.

oxide, or *Manganous hydrate*, is obtained by precipitating a
tic potash, as a white, milky, flocculent precipitate, which, on
brown by oxidation, and is ultimately converted into man-
e change is produced immediately by chlorine-water, or the
. If it be washed in an apparatus from which the air is
s possible, then dried in a stream of hydrogen, and heated in
to drive off the water, the remaining protoxide is sometimes
ed-hot coal is laid upon it, it glows from the point of contact
s, and is converted into manganic oxide. According to H.
ns 24 per cent. water.

drate dissolve readily in nitric, sulphuric, and hydrochloric
manganous salts.

ganic oxide, Mn^2O^3.—This oxide occurs native, as *Braunite*,
amids, in which the principal is to the secondary axes
he terminal edges = 109° 53′; of the lateral edges = 180° 39′.
el to P, none parallel to oP. It occurs also massive.
ecific gravity = 4·75—4·818. Lustre submetallic. Streak
h-black. Fracture uneven. Brittle. Infusible before the
veins traversing porphyry at Oehrenstock near Ilmenau; at
; also near Ihlefeld in the Hartz; at St. Marcel in Pied-
a; at Vizianagram in India; and in the state of Vermont

Analyses of Braunite.

Locality .	*Eglersberg.*	*Tellemark.*	*Elba.*	*St. Marcel.*
Analyst .	Turner.	Tonsager.	Bechi.	Damour.
se . .	96·71	95·83	91·42	96·62
. .	. .	1·74	4·75	1·45
. .	2·26	. .	1·03	
. .	. .	. .	. .	1·22
. .	0·95	2·19	2·08	
	99·92	99·76	99·28	99·64

ined as a black powder by heating manganous nitrate, per-
anganic hydrate to low redness, the hydrate perhaps yielding
. If the heat is too strong, the residue consists of manganoso-

ider (Pogg. Ann. cvii. 605) all the lower oxides of manganese
xide by strong ignition in oxygen gas.
of Dittmar (Chem. Soc. J. xvii. 294) it appears that the
ct obtained by heating an oxide of manganese depends upon
in the surrounding atmosphere as well as on the temperature.
anganese to bright redness in pure oxygen of various tensions,
of oxygen and nitrogen, and in pure nitrogen, it was found
the oxygen was between 0 and 0·21 atmosphere, manganoso-
med; but when the oxygen-tension was between 0·26 and
ioxide was obtained. The exact limit of tension which

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determines the stability of one or the other oxide a
perature.

Manganic oxide when strongly ignited in a close
oxygen, and leaves manganoso-manganic oxide. By b
dilute sulphuric acid, it is resolved into protoxide, whic
remains undissolved. Hot strong sulphuric acid reduc
dissolves it, with evolution of oxygen gas. Hot hydr
evolution of chlorine.

Hydrated Manganic oxide, or *Manganic Hydrate*, Mn^2

compound is found native, as *Manganite* or *Grey Man*
porphyry, at Ihlefeld, in the Harz; at Ilmenau and Oeh
deenshire; at Undenaes in Sweden; and at Christiansan
crystals, usually exhibiting the face ∞P with $\infty \breve{P}\frac{3}{2}$ and
with oP and $\breve{P}\infty$, or a pyramid $\breve{P}3$, &c. Ratio of axes,
$\infty P : \infty P = 80° 20'$; $\infty P : \infty \breve{P}\frac{3}{2} = 103° 23'$; $\breve{P}\infty : \breve{P}$
plane of combination $\breve{P}\infty$. Cleavage very perfect, paral
longitudinally striated and often grouped. The mine
granular. Hardness = 4. Specific gravity = 4·2—4·4
dark steel-grey to iron-black. Streak reddish-brown, so
minute splinters sometimes brown by transmitted lig
before the blowpipe.

Analyses of Manganite.

	West Gothland. Arfvedson.	Gmelin
Manganese . . .	89·92	62·86
Oxygen . . .		27·64
Water . . .	10·08	9·50
	100·00	100·00

Manganic hydrate is prepared artificially by exposi
the air, or by passing chlorine, not to saturation, i
carbonate is suspended, decanting the liquid, and dig
containing manganous carbonate, in cold very dilute ni
manganous oxide; when prepared by this latter proc
with hydrated peroxide.

Manganous hydrate artificially prepared is a light
colour and capable of soiling very strongly. It gives
above 100°. By boiling with moderately concentrated
protoxide, which dissolves, and a residue of hydrated p

Manganic oxide dissolves without decomposition in
manganic chloride. Strong sulphuric acid combines with
100°, but does not form a solution. Dilute sulphuric
manganous oxide is present, even in very small quant
tion is formed. (Carius.)

A manganic sulphate may be prepared by mixing f
ganese with monohydrated sulphuric acid to the consi
heating the mixture to 135°. It may be heated to 160
decomposed at higher temperatures into oxygen and m
quickly reduced by organic substances, and decompos
manganous hydrate (Carius, Ann. Ch. Pharm. xcviii
the simple manganic salts is the phosphate, which dis
position.

Generally speaking, however, manganic oxide does
unless another base or protoxide is present: with sulp
several double salts having the constitution of alum
potassic sulphate found native on the shores of the Gr

Manganoso-manganic oxide, or **Red oxide**
$MnO.Mn^2O^3$.—This oxide occurs native, as *Hausma*
manganese ores, with porphyry, near Ilmenau in Thu
Harz. The crystals are acute quadratic pyramids, i
secondary axes as 1·175 : 1. Angle P : P in the tern
lateral edges = 117° 54'. Cleavage basal, nearly perfe
the face of combination being parallel to $P\infty$, the same
occurring between two individuals. Also granular
Hardness = 5 to 5·5. Specific gravity = 4·722. Lustre

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own. Opaque. Fracture uneven. Infusible before the

Analyses of Hausmannite.

	Ilefeld. Turner.	*Ilmenau.* Rammelsberg.
anganese . . .	98·902	99·44
. . . . .	0·215	0·05
. . . . .	0·111	0·15
. . . . .	0·337	
. . . . .	0·435	
	100·00	99·64

sily obtained by artificial means of all the oxides of man-ed when manganous oxide, nitrate, or carbonate, is strongly air, or when either of the higher oxides is subjected to very anganese, exposed to moist air at ordinary temperatures, culiar odour, and is converted into a reddish-brown powder, ganese containing charcoal and silicium, with manganoso-solves in hydrochloric acid, with evolution of hydrogen gas, on, which, when heated, becomes colourless and gives off kes place more rapidly, in proportion as the manganese is d the air is warmer and contains more moisture. If the he conversion into manganoso-manganic oxide takes place incandescence; in oxygen gas, the finely-divided metal oxide is also produced, with evolution of hydrogen, by tream of aqueous vapour. It is a reddish-brown or cinna- turns black when heated, but recovers its original colour to whiteness with charcoal, it is reduced to metallic man- dilute sulphuric or with nitric acid, it is resolved, like the and peroxide; hot strong sulphuric acid dissolves it as beration of oxygen; hot hydrochloric acid, with liberation of out decomposition in a hot, very strong solution of phos- ncentrated sulphuric, hydrochloric, oxalic, or tartaric acid, and without neutralising the acid. The solutions, treated brown precipitate, perhaps consisting of manganoso-man- the addition of water, or of deoxidising agents, converts xcepted) into salts of manganous oxide, with a large excess

MnO^2.—This oxide occurs in nature as *Pyrolusite* or als exhibiting the combination $\infty\breve{P}\infty . \infty P . \infty\bar{P}\infty . oP . \frac{1}{2}\bar{P}\infty$. 6 : 1 : 1·066. Angle $\infty P : \infty P = 93° 40'$. Also columnar, lar, massive, and frequently in reniform coats; often soils. cific gravity = 4·819 (Turner); 4·97 when pure. Lustre dark steel-grey, sometimes bluish. Streak black. Opaque. alone before the blowpipe; gives off oxygen on char- of manganese, and is extensively worked at Eglersberg, in Thuringia; also at Vorderehrensdorf near Mährisch- place affords annually many tons of the ore. It also occurs lomelane in many parts of the United States.

Analyses of Pyrolusite.

Devon-shire.	*Eglers-burg.*	*Ihle-feld.*	*Ilme-nau.*	*Undenaes.*	*Tarn.*	*Krett-nich.*	Calcu-lated Mn^2O^2.
Turner.			Schet-fler.	Arfved-son.	Dufres-noy.	Riegel.	
85·62	84·05	85·62	87·0	83·56	72·5	86·00	87·74
11·60	11·78	11·60	11·6	14·58	9·8	11·45	12·26
. .	. .	. .	1·3	. .	4·2	0·40	
. .	. .	. .	0·3				
0·67	0·53	0·66	1·2				
. .	. .	. .	0·3	. .	. .	trace	
0·55	0·51	0·55	0·8	. .	1·4	0·71	
1·56	1·12	1·57	5·8	1·86	1·6	1·40	
00·00	97·99	100·00	108·3	100·00	99·5	99·96	100·00

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Peroxide of manganese is prepared by the following manganic or manganic oxide, is boiled with strong nitric is gradually heated to incipient redness, and the res boiling nitric acid from any remaining manganous oxide; washed and very carefully heated to low redness, stirrin —3. Manganous carbonate is heated in an open vessel carbonate which may then remain undecomposed, are rem hydrochloric acid; whereupon, according to Forchham behind.—4. Manganous carbonate is carefully heated with and the mass, when cold, is well washed with water (Göb ganous salt, even when very dilute, provided it is perfe peroxide of manganese on the positive pole of a voltaic sufficient for the purpose (Fischer, Kastn. Arch. xvi. 219 oxide of manganese is black with submetallic lustre, hard

Peroxide of manganese, whether natural or artificial, tricity, and is remarkable for its tendency to become strong with metals, so that powerful voltaic combinations may b plate covered with it as the negative element. Discs of oxide are also used in the construction of dry piles. (See

The peroxide when *heated* alone gives off part of its oxy ganic or manganoso-manganic oxide, according to the degre position takes place more readily in open than in closed ve a charcoal-lined crucible, it is reduced to protoxide, and if ganous oxysulphide, with evolution of sulphurous anhyd strong *sulphuric acid*, it gives off one-fourth of its oxygen tion of manganic sulphate; and on heating the mixture oxygen is given off and manganous sulphate is produced facilitated by mixing the peroxide with organic substances, s carbonic anhydride being then evolved instead of oxyg *acid* it forms manganic chloride; on heating, manganous chlorine. With *sulphurous acid*, it forms a solution con and hyposulphate. By ignition with *potash* in a close ve ganous oxide and manganic acid.

The facility with which peroxide of manganese parts renders it a very valuable oxidising agent, both in the manufactures. It is extensively used for the evolution o acid (i. 890), also for discharging the brown and green tin *pyrolusite* (from πῦρ fire, and λούω to wash) applied to t somewhat whimsical title, *savon des verriers*, given to it by

Hydrates of the Peroxide.—Peroxide of manganese unit portions, according to the mode of preparation.—*α.* In th of manganates or permanganates dissolved in water or i hydrated peroxide is precipitated, which cakes together to taining $MnO^2.H^2O$ (Mitscherlich). The same hydrat carbonate suspended in water is treated with chlorine, an well washed with dilute acid (Berthier).—*β.* A hydrate obtained when a solution of a manganous salt is precipita potash and potassic hypochlorite (Winkelblech).—*γ.* T deposited on evaporating a solution of manganous bro *δ.* $4MnO^2.H^2O$ is obtained by treating manganoso-man nitric acid (Berthier). See *Gmelin's Handbook*, iii. 206

According to Görgeu (Ann. Ch. Phys. [3] lxvi. 155; oxide of manganese acts as an acid, uniting with bases, an when suspended in perfectly pure water; hence Görgeu pro acid. (See MANGANIC ACIDS, p. 817.)

Oxides of Manganese intermediate in composition be Dioxide.—Under this head are included several ores of ma one or two of definite constitution, but the greater n different oxides, which cannot be regarded as definite che mineral species.

α. Psilomelane. $RO.MnO^2.H^2O$, with excess of peroxi the symbol RO denotes protoxide of manganese, partly re chiefly baryta and potash. This ore occurs massive = 5 to 6. Specific gravity = 3·7 to 4·328. Lustre subm black, shining. Colour iron-black, passing into dark st common ore of manganese, occurring frequently in alter It is found in botryoïdal and stalactitic shapes in De Ihlefeld in the Harts, and the other localities undermentio

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Analyses of Psilomelane.

Romanèche.	Florhausen.	Baireuth.	Ilmenau.	Thiviers.	Heidelberg.	Ilmenau.	Langenberg.
rner.	Rammelsberg.	Fuchs.	Scheffer.	Berthier.	Rammelsberg.	Clausbruch.	Heyl.
70·97	81·36	81·8	73·3	64·1	70·17	77·23	68·00
7·26	9·18	9·5	9·8	7·5	15·16	15·82	13·62
. .	1·43	. .	0·3	6·8			
. .	0·96	. .	. .	. .	0·30	0·40	0·36
. .	. .	. .	. .	. .	0·54		
. .	. .	. .	2·1				
. .	0·38	. .	1·8	. .	0·60	0·91	0·20
. .	0·32	. .	. .	. .	0·21	. .	0·53
16·69	. .	. .	5·8	4·6	8·08	0·12	8·59
. .	3·04	4·5	. .	. .	2·62	5·29	0·27
0·95	0·53	. .	1·7	10·0	0·90	0·52	2·18
4·13	3·39	4·2	4·3	7·0	1·42	. .	3·95
100·00	100·59	100·0	99·1	100·0	100·00	100·29	97·70

rom Warwickshire, of crystalline-laminated texture, and spe- was found by R. Phillips to contain 63 per cent. manganese, agreeing nearly with the formula $Mn^2O.3Mn^2O^2.H^2O$. It ganite consisting largely of pyrolusite.

, Cupreous Manganese.—These ores occur in amorphous earthy or compact, sometimes encrusting or as stains. They ides, and not distinct mineral species. Their hardness varies ity from 3 to 4·26; colour dull black.

Analyses of Wad.

Devonshire.	Derbyshire.	Vicdessos	Gravel.	Siegen.	Rübeln.	Austerlitz, N. Y.	Skidberg.
Turner.		Berthier.			Rammelsberg.		Bahr.
74·60	34·73	69·8	62·4	58·5	67·50	52·65	61·54
13·34	3·86	11·7	12·8	10·4	13·48	5·85	4·62
. .	52·34	. .	6·0	5·7	1·01	22·00	2·70
. .	. .	. .	. .	. .	. .	. .	0·02
. .	. .	7·0	. .	10·7	. .	. .	0·75
1·40	5·40	. .	. .	. .	0·36	. .	15·34
. .	. .	. .	. .	. .	4·22	. .	0·59
. .	. .	. .	. .	. .	. .	. .	0·28
. .	. .	. .	. .	. .	3·66	. .	0·28
. .	2·74	. .	3·0	1·8	0·47	2·50	0·92
10·66	10·29	12·4	15·8	12·9	10·30	17·00	12·07
100·00	109·36	100·9	100·0	100·0	101·00	100·00	99·11

yses of Manganese-ores (continued).

Cupreous Manganese.			Earthy Cobalt.		
Camsdorf.		Lauterberg.	Oberlausitz.	Camsdorf.	
Rammelsberg.	Böttger.		Klaproth.	Döbereiner.	Rammelsberg.
49·99	53·22	27·04	14·4	31·21	40·05
8·91	9·14	3·01	1·6	6·78	9·47
4·70	1·88	29·00	. .	. .	4·56
14·67	16·85	11·50	0·2	. .	4·35
0·49	0·14	. .	19·4	32·05	19·45
. .	. .	. .	20·4		
1·64	1·70	. .	. .	. .	0 50
2·25	2·85				
0·69					
0·52	0·65	. .	. .	. .	0·37
2·74	. .	. .	24·8		
14·46	16·94	27·45	17·0	22·90	21·24
101·06	103·37	98·00	97·8	92·94	99·99

consists mainly of oxides of manganese and water, often lime, or baryta. *Groroïlite* occurs in roundish masses of

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brownish-black colour and reddish-brown streak: hardn
from Groroi in Mayence, Viedessos in Spain, and Cantee

Cupreous Manganese contains, besides hydrous oxides
per cent. oxide of copper, and 4 to 18 per cent. oxide of
Specific gravity 3·1 to 3·2. *Pelokonite* is a variety of
liver-brown streak. Hardness = 3. Specific gravity

Earthy Cobalt is a wad in which oxide of cobalt some
33 per cent.

Valuation of the Oxides of Mang

The numerous applications of the higher oxides of ma
tures, depend upon the quantity of oxygen which they
the action of acids, or—what comes to the same thing—
they are capable of eliminating when treated with hyd
seen from the following equations, which represent the
the dioxide, sesquioxide, and red oxide of manganese:

$$\underset{\text{Dioxide.}}{MnO^2} + 4HCl = MnCl^2 + 2H$$

$$\underset{\text{Sesquioxide.}}{Mn^2O^3} + 6HCl = 2MnCl^2 + 3H$$

$$\underset{\text{Red oxide.}}{Mn^3O^4} + 8HCl = 3MnCl^2 + 4H$$

Hence it appears that the quantities of hydrochloric a
quantity of chlorine, when acted upon by these three
2 : 3 : 4; or a given weight of hydrochloric acid, acted
yield quantities of chlorine in the inverse ratio of these

Moreover, as the sesquioxide and red oxide may be re
composition is concerned) as compounds of the protoxide
MnO^2; and $Mn^3O^4 = 2MnO + MnO^2$), it follows that th
ganese-ore may be regarded as proportional to the perc
contained in it.

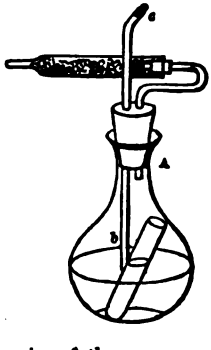
The methods of assaying the oxides of manganese
heads:—1. The determination of the amount of oxy
acid.—2. The oxidation of oxalic acid.—3. The evolutio
acid.

a. The decomposition of peroxide of manganese by
represented by the equation:

$$MnO^2 + H^2SO^4 = MnSO^4 + H$$

The sample of manganese ore to be tested is heated w
small retort provided with a bent delivery-tube passing
jar, filled with and standing in an alkaline liquid, so th
may pass over may be absorbed, and the oxygen alone co
retort are heated to the boiling point, the heat being c
disengaged. The apparatus is then left to cool, and the
corrected for pressure, temper
vapour.

Fig. 731.



Each atomic proportion (1
evolved corresponds to 1 at. pe
Moreover, as the reaction is
composition of the peroxide
of oxygen evolved in the one
chlorine eliminated in the oth

β. By *oxidation of oxalic*
heated with peroxide of mang
the disengaged chlorine conv
bonic anhydride, 2 at. carbo
senting 2 at. chlorine, and the
ganese:

$$\underset{\text{Oxalic acid.}}{C^2H^2O^4} + Cl^2 =$$

The quantity of carbonic anhy
mined by means of the flask
731, and already described un
grains of the manganese-ore finely pulverised are introd
with half an ounce of cold water and 100 grains of strong

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ised oxalic acid are then added, the chloride of calcium tube
kly weighed; and the process conducted exactly in the same
on of carbonic anhydride, as described in the article above
eight of the flask after boiling, gives the quantity of carbonic
87—the atomic weight of peroxide of manganese—is nearly
ydride, 44, the loss of weight in the apparatus may be taken
the quantity of real peroxide in the 50 grains of the sample.
s easily made.

cid oxidised by a given sample of a manganese-ore may also
lly by means of *permanganate of potassium*. A dilute solu-
ses permanganates, in presence of sulphuric acid, being itself
ydride and water, according to the equation:

$$5C^2H^2O^4 + 2MnSO^4 + 8H^2O + 10CO^2.$$

Oxalic acid. Manganous sulphate.

nces, oxalic acid decomposes peroxide of manganese, atom

$$C^2H^2O^4 + MnSO^4 + 2H^2O + 2CO^2.$$

xide of manganese in an ore may be estimated volumetri-
upon a known volume of a standard solution of oxalic acid,
nd then estimating the amount of undecomposed oxalic acid
ermanganate.

required are: 1. *Oxalic acid.*—1 cub. cent. of this solution
c acid, and corresponds to 0·042 grm. peroxide of manganese.
solution cannot be preserved without decomposition, and is
once for all; but a moderately strong solution is prepared,
ined before each operation. This is readily done by means
f oxalic acid. 5 c. c. of the latter are diluted to 200 c. c.;
phuric acid are added; and the permanganate solution is
rom a burette. The dark colour produced by the perman-
at first, but more rapidly as the operation proceeds; the
hen a faint rose tinge is produced, which remains permanent
, for instance, 29 c. c. of the permanganate solution are re-

s solution corresponds to $\frac{5}{29} = 0{\cdot}1724$ c. c. of oxalic acid.

ted as follows:—The ore having been finely powdered and
. are treated with about 30 c. c. standard oxalic acid, and
lphuric acid; when the evolution of carbonic anhydride
ll no more gas is evolved. If any of the ore remains unde-
e oxalic acid must be added. When the evolution of gas has
tion is decanted into a graduated cylinder, and the residue is
ore oxalic acid, and a few drops of sulphuric acid, and again
position is complete, the solution (residue and all) is washed
whole is diluted to a known volume. The mixture thus
ut it need not be filtered, unless it is dark-coloured. A
asured off, diluted, acidulated with sulphuric acid, and the
xalic acid is estimated by the permanganate solution, as
us obtained, the amount of non-oxidised oxalic acid in the
l. The number of cubic centimetres of oxalic acid oxidised,
ercentage of peroxide of manganese in the ore. For example,
ion = 0·1724 oxalic acid. Weight of ore taken = 2·1 grms.
d = 48 c. c. The mixture being diluted to 300 c. c., 100 c. c.
te: hence, the whole 300 c. c. require 12 c. c. permanganate,
. c. oxalic acid. 48 − 2·07 = 45·93 c. c. oxalic acid, oxidised
entage of peroxide = 45·93 × 2 = 91·86 per cent.
, any arbitrary weight of the ore is taken, the amount of
he proportion 100 : 4·2 = number of c. c. oxalic acid used:
entage is then calculated as usual.

Chlorine from Hydrochloric acid.—The ore (the moisture in
heated in a flask with excess of concentrated hydrochloric
evolved is conducted into a known volume of a standard
s solution, or into excess of iodide of potassium, or into
eight of ferrous sulphate, that salt being in excess, and
estimated by one of the chlorimetric processes described
TION OF (i. 904). The amount of peroxide of manganese,

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corresponding to a given weight of chlorine, is calculated
= 71 : 87.

Each c. c. of the acid arsenious solution (i. 904) corres
and to 0·01183, peroxide of manganese; hence 50 c. c. co
and to 0·5915 peroxide. If the ore is rich, about 1 grm.
if it be poor, from 1·5 to 2 grm. should be taken.

Each c. c. of the alkaline arsenious solution (i. 904)
chlorine, and to 0·0042 grm. peroxide; hence 100 c. c.
oxide; and if 0·42 grm. be taken for analysis, the numl
which is oxidised by it gives at once the percentage of p
book of Chemical Analysis, p. 247.)

MANGANESE, OXYCHLORIDE OF. The
scribed by Dumas (p. 805) is perhaps an oxychloride.

MANGANESE, OXYSULPHIDE OF. MnSO.
when manganous sulphate is ignited in a stream of
sulphide of manganese, when an oxide of manganese is ig
It is a green powder which does not alter at ordinary
when heated, and burns to nearly pure manganoso-
strongly heated at the last. It dissolves in acids as eas
prepared in the wet way. (Arfvedson.)

MANGANESE, PHOSPHIDE OF. Obtained by
of 10 pts. of pure ignited dioxide of manganese, 10 pts
of white quartz-sand, and 3 pts. of ignited lamp-black f
crucible, to a heat sufficient to melt cast iron; or by
ignited phosphate of manganese, 3 pts. of ignited lamp
borax in a crucible lined with charcoal. The product
regulus of the colour of grey cast iron, and of specific gr
in the air, glows when heated in contact with air, burn
heated with nitre. It appears to contain Mn^3P^2, and is
and MnP^2, the latter of which compounds is left behind
with hydrochloric acid, while the former dissolves, with e
inflammable phosphoretted hydrogen. (Wöhler, Ann.
Schrötter (Jahresb. 1849, p. 247), by heating finely
phorus-vapour, obtained a phosphite having the composit
4·94, insoluble in hydrochloric acid, easily soluble in nitr

MANGANESE, SILICIDE OF. The effect attr
silicium in altering the physical properties of metallic
mentioned (p. 802). Wöhler (Ann. Ch. Pharm. cvi. 54
question by preparing manganese containing larger propor
of about equal parts of fluoride of manganese, water-glass,
into a hessian crucible, and covered with a mixture of chlo
of sodium, then heated and exposed to a higher temperatu
brittle regulus containing 11·7 per cent. silicium, exhibitin
line structure on the fractured surface, but without visible s
action of hydrochloric acid upon it was considerably in
oxide of silicium, very dense but not crystalline; the hyd
time contained siliciuretted hydrogen, and deposited amo
through a red-hot glass tube; hydrofluoric acid dissolve
hydrogen gas. A mixture of fused chloride of manganese
glass and sodium yielded a well fused, very brittle regu
silicium, and exhibiting a few cavities filled with steel-gre
ture of fused manganous chloride, fluor-spar, silico-fluori
yielded (after somewhat quicker cooling) a nearly silv
containing 6·5 per cent. silicium and having a conchoïdal
mixture of manganous chloride, sodium, fine quartz-sand
in the proportion of 22 : 26) yielded a yellowish regul
silicium, with indications of laminar structure. From
clined to believe that even a small quantity of silicium is
peculiarities of the metallic manganese obtained by Brun

MANGANESE, RED. Native carbonate of ma
(i. 788).

MANGANESE, SULPHIDE OF. *Manganous*
only known sulphide of manganese, occurs native as *Ma*
in the gold mine of Nagyag in Transylvania, some
and regular octahedrons, with perfect cubic cleavage,
larly massive. Hardness = 3·5 to 4. Specific gravity =

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ack colour, tarnished brown on exposure. Streak green.
e the blowpipe it melts only on the thinnest edges.
oduced artificially in the dry way, by heating the peroxide
anhydride is disengaged and a green powder remains,
ith evolution of sulphydric acid. The same compound is
ate by decomposing acetate of manganese with sulphydric
with sulphide of ammonium.
manganese is obtained by passing the vapour of sulphide of
anic oxide ignited in a porcelain tube. The crystals are
aving a tinge of green and yielding a dingy green powder.
ganous sulphide soon turns brown by oxidation on exposure
n the air, it easily gives off all its sulphur as sulphurous
anoso-manganic oxide. Heated in hydrogen gas, it gives
onates when heated with nitre. Chlorine acts but slowly
ulphur. The hydrated sulphide boiled with potash, yields
anganous hydrate.
lves very easily in acids, even in acetic acid; sulphurous
lphite with separation of sulphur. When the precipitate is
utral metallic solutions, *e. g.* sulphate of cadmium, acetate
te of silver, sulphate of copper, &c., these metals unite with
ese is taken up in their place.
s definite compounds with the sulphides of potassium and
lt, $K^2S.3MnS$ or $Mn^3K^2S^4$, is prepared:—1. By fusing
hate with $\frac{1}{5}$ of its weight of lamp-black, and 3 times its
ssium and sulphur. A gentle heat is applied at first, till
expelled and sulphide of potassium formed; afterwards
redness. On cooling, a perfectly fused mass is obtained,
ulphide of potassium has been removed by cold water pre-
. leaves large dark red scales collected together in masses:
split, like mica, into thin, transparent, dark red laminæ.
de of manganese for the manganous sulphate, a similar
f less brilliant colour.—The scales, when moist, are rapidly
g black and opaque; but, when perfectly dry, they remain
e time. They are nearly insoluble in water, alcohol, and
ntly with nitre. Acids dissolve them, with rapid evolution
hen heated on platinum wire, they become covered with a
le of manganese. They are gradually dissolved by water
and sulphide of potassium, and manganous hyposulphite,
luble mixture of sulphur and manganic oxide. (Völker,

^{4}, obtained in a similar manner to the potassium compound,
ed needle-shaped crystals, resembling those of sulphide of
in most of their properties, but more readily oxidisable.
water, they rapidly become opaque and dark-coloured. If
over oil of vitriol in a vacuum, they rapidly absorb oxygen
erately dry; and the absorption is attended with so violent
at the crystals frequently take fire, and burn like a pyro-

M. *Manganico-potassic sulphate*, $\left.\begin{matrix}(S''O^2)^2\\ Mn'''\\ K\end{matrix}\right\}O^4.12H^2O$, found

Great Salt Lake.—A *manganese-magnesium alum* has been
Switzerland. (See SULPHATES.)

NDE. Native manganous sulphide (p. 816).

NCE. Syn. with MANGANESE-BLENDE.

R. Syn. with DIALLOGITE. Native carbonate of manganese.

. Two oxygen-acids of manganese have long been known,
permanganic acid, the potassium-salts of which are
:

ium	MnK^2O^4
tassium	$Mn^2K^2O^8$.

in the free state; but permanganic acid, $Mn^2H^2O^8$, has been
pears to be capable of existing in the solid state. The an-
hese acids, viz. MnO^3 and Mn^2O^7, have not been obtained.

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Recent experiments by Gorgeu (Ann. Ch. Phys. [3
that dioxide of manganese, MnO^2, is capable of uniti
forming salts which may be called manganites. They
sition $R^2O.5MnO^2$ (R denoting a monatomic metal). T
in water; the calcium-salt is a brown precipitate, obtai
manganous nitrate to hypochlorite of calcium.

Manganates. MnR^2O^4.—These salts are isomorphc
ates, and chromates. Only three of them have, howe
barium-, potassium-, and calcium-salts. They have a
unstable, especially in solution, being quickly converte
separation of manganic oxide: the decomposition is acc
acids, and retarded by alkalis.

Manganate of Barium. $MnBaO^4$.—This salt is o
of manganese with nitrate of barium, or better, by adding
and by small portions, to a mixture of hydrate of barium
heated to fusion, and afterwards dissolving out the chl
It is a green powder, insoluble in water. It may, h
crystalline state by mixing a solution of permanganate o
and leaving the liquid to stand in a loosely-covered vessel

Manganate of Potassium. MnK^2O^4.—When diox
ignited with hydrate or carbonate of potassium in excess, m
the influence of the alkali, together with a lower oxide of
vessels, or with an admixture of nitrate of potassium, inc
acid, by the absorption of oxygen which then occurs. The
as *mineral chameleon*, from the property of its solution, w
rapidly through several shades of colour. A more conv
manganate of potassium is that recommended by Dr. Gr
4 pts. of dioxide of manganese in fine powder with 3½ pts.
adds the mixture to 5 pts. of hydrate of potassium dissolve
The mixture is evaporated to dryness, powdered, and afte
crucible, but not fused, at a low red heat. The ignited ma
tity of cold water, forms a deep green solution of the alk
be obtained in crystals of the same colour by evaporatin
acid in a vacuum.

Manganate of potassium is not soluble in water wit
water is poured upon the crystals, they are resolved into
and a black crystalline compound of potash with peroxi
of potassium) which almost immediately gives up its pot
pure hydrated peroxide of manganese. (Mitscherlich

$$\underset{\text{Manganate.}}{3MnK^2O^4} + 2H^2O = \underset{\text{Permanganate.}}{Mn^2K^2O^8} + 4KH$$

According to Gorgeu (*loc. cit.*), when carbonic anhydride
of potassic manganate till the alkali is completely conver
ganate of potassium is formed, together with a yellow hy
manganite of potassium, $K^2O.5MnO^2$, or $Mn^5K^2O^{11}$.

Manganate of potassium dissolves without decompositi
alkali. If potash be added, not in too great excess, b
green solution, this solution sometimes turns red when w
cooling; but if briskly stirred, it turns green again.

When a very strong solution of potassic manganate is
potash has absorbed carbonic acid, crystals are sometimes
to Mitscherlich, of *acid manganate of potassium*, MnKHC

Manganate of Sodium.—Obtained by igniting peroxi
soda. It is so very soluble in water, that it cannot be obt
(Mitscherlich). According to Gentele, however (J.
ganate of sodium is obtained in nearly colourless crystal
and containing $MnNa^2O^4.10H^2O$, by heating equal parts o
of manganese and nitrate of sodium in a muffle to a br
boiling the pulverised black mass with water, and leaving
cold place. The crystals dissolve in water with slight dec
solution. According to Wöhler (Ann. Ch. Pharm. cxi
this process does not yield a trace of sodic manganate, beca
decomposed before the temperature required for the form
attained; in fact, the decomposition is so complete, that th
the preparation of pure hydrate of sodium. [But why doe
act on the peroxide of manganese so as to form sodic man

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$Mn^2R^2O^8$.—These salts are more stable than the manganates, d by their oxidation. They are isomorphous with the per- which affords a strong argument in favour of the diatomicity as if the metal be regarded as monatomic, the formulæ of perchlorates do not exactly correspond, the one containing ier contains only 1 at. Cl.

mmonium. $Mn^2(NH^4)^2O^8$.—When permanganate of silver valent quantity of sal-ammoniac and with water, a purple-red , when decanted from separated chloride of silver, yields by esponding in composition with the above formula, and not rystallisation. They are trimetric, and similar in form to the somewhat different angles: $a : b : c = 0{\cdot}8050 : 1 : 0{\cdot}6519$. $: \breve{P}\infty = 78° 0'$. When dried by heat, they quickly decompose.

Barium. Mn^2BaO^8.—This salt may be prepared by passing igh water in which impure manganate of barium, obtained f manganese with nitrate of barium, is suspended, till decomposed, then decanting, boiling for a while in order ting acid carbonate of barium, and evaporating the clear ing point. Or permanganate of silver is decomposed by an hloride of barium dissolved in water, and the solution is

m forms black prisms, permanent in the air, and isomorphous and selenate of sodium (Mitscherlich). When the red xed with baryta-water, it acquires a violet colour, loses after a ion, and yields by evaporation crystals of manganate of

calcium, *copper*, *magnesium*, *sodium*, *strontium*, and *zinc* are ium-salt: they are deliquescent and difficult to crystallise. ses more rapidly.

Hydrogen, or Permanganic acid. $Mn^2H^2O^8$.—This the state of aqueous solution, by decomposing the barium-salt thus obtained by Mitscherlich, the free acid appeared to be a n peroxide of hydrogen, being decomposed between 30° and en gas and precipitation of hydrated peroxide of manganese. nd was rapidly destroyed by all kinds of organic matter. and, obtained permanganic acid in a state in which it could redissolved, &c. He washed the manganate of barium with is resolved into dioxide of manganese and permanganate of to it the quantity of phosphoric acid exactly necessary to neu- liberated permanganic acid was dissolved out, evaporated to solution and evaporation, obtained in the form of a reddish- and radiated, which exhibited the lustre of indigo at some oluble in water. When the dry permanganic acid was fused us sulphuric acid, and afterwards distilled at a higher tem- limate of a crimson red colour was obtained, which appeared ermanganic and sulphuric acids. (Berzelius' *Traité*, i. 522.) phuric acid is poured upon a somewhat considerable quantity ate of potassium, the salt is decomposed, with great evolution of out, oxygen being given off, and manganic oxide being set and shreds like spider-lines. The red flames seem to show gaseous at the high temperature produced by the reaction. rther demonstrated by Terreil (Bull. Soc. Chim. de Paris, use of this property to obtain the acid in the pure state. For te of potassium is dissolved in sulphuric acid (H^2SO^4) diluted e greenish-yellow solution is distilled over the water-bath at tus then becomes filled with violet vapours, which condense k liquid, not containing either chlorine or sulphuric acid, but nganic acid. It is difficult, however, to prepare a large quan- this manner, inasmuch as, at a certain moment, as soon as llate has become somewhat considerable, it decomposes spon- tonation and separation of manganic oxide.

s obtained is a thick, greenish-black, metallic-shining liquid, ble of solidifying. It greedily attracts moisture; its solution d, if protected from dust, may, when dilute, be preserved When quickly heated, it detonates; but if slowly warmed, it

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volatilises in violet vapours, having a peculiar metallic o
oxidising power, instantly setting fire to paper and alco
In contact with fatty bodies, it detonates with violence.
sulphite of potassium are let fall on permanganic acid, a
part of the acid is carried forward in vapour, and
diffuses through the air, depositing a shower of brown
solves to a certain extent with green colour in strong su
acid containing 3 at. water, is violet; a difference which
of an anhydrous and a hydrated permanganic acid. (T

Permanganate of Lead, Mn^2PbO^8, is formed, on
of lead with permanganate of potassium, as a brown pre
in nitric acid.

Permanganate of Potassium. $Mn^2K^2O^8$.—Thi
following processes:—1. One pt. of peroxide of mang
hydrate of potassium (or 1·8 of nitre); the resulting
the red solution decanted and evaporated, rapidly at fi
afterwards cautiously, so that the crystallisation may go
Edwards).—2. Chlorate of potassium being kept in a
lamp, hydrate of potassium is first added to it, and th
peroxide of manganese, which immediately dissolves, forn
The mixture is then heated till the whole of the chlorate
when cold, is boiled with a small quantity of water, whe
solution changes to red; finally, the liquid is decanted fr
while still hot, and set aside to crystallise by cooling (W
Gregory (J. Pharm. xxi. 312) adds a solution of 10 p
sium in a very small quantity of water to a finely-divid
peroxide of manganese and 7 pts. (1 at.) of chlorate of
ness, during which a small quantity of mineral chameleo
powdered mass in a platinum crucible over a spirit-lamp
of potassium is decomposed (for which a low red heat i
semi-fused mass to coarse powder; boils it in a larger
insoluble portion to subside, and decants; evaporates th
decants from the freshly precipitated peroxide of mang
to crystallise by cooling. The crystals are then washed
water; dissolved in the smallest possible quantity of b
is left to crystallise by cooling. In this manner needles
an inch in length, and amounting in weight to about a t
nese employed. If it be desired to filter the solution, in
from decantation, a funnel may be used, having its neck

The salt crystallises in dark purple-red needles, havin
a rough taste; it does not redden turmeric, and is perma
are trimetric; $a : b : c = 0{\cdot}79523 : 1 : 0{\cdot}6478$; $\infty P : \infty P =$
They are prismatic, exhibiting the combination $\infty P . P\infty$
frequently, also, with oP and other faces. The salt diss

The crystals decrepitate when *heated*, evolve 10·8 pe
converted into a black powder from which water extr
leaving 54 per cent. of black manganic oxide. When
hydrogen gas, they become red-hot and diminish in bul
slowly, with formation of a green mixture of hydrate o
manganese. The salt, when triturated with *sulphur*, proc
tions. Mixed with an equal weight of sulphur and hea
flame. *Phosphorus* produces a much louder detonation
when heated with it to 70°. *Charcoal*, *arsenic*, and *ant*
heated with the salt.

A solution of permanganate of potassium containing *per*
taining the two salts in the same proportion as the sol
large excess of perchlorate, they are red; but if the propor
to one half, they appear black.

Permanganate of Silver, $Mn^2Ag^2O^8$, is obtained,
mixing warm solutions of nitrate of silver and permang
tion as it cools depositing the salt in large regular cry
their weight of water at 15° to dissolve them. In war
soluble, but they cannot sustain a boiling heat without d

The manganates and permanganates, especially the
agents for a variety of purposes. A solution of permang
deoxidised, and consequently decolorised, by sulphurous

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ates, and by acid solutions of sulphites, hyposulphites, tetra- and nitrites; more slowly by trithionates. Acidulated rrous, stannous and antimonious salts, and acid solutions of pidly decolorise a solution of a permanganate. A solution of n constitutes a test-liquid of great use in volumetric analysis, casion to notice (see i. 263; ii. 59; iii. 384).

rmanganates likewise act very rapidly on organic matter, and l as disinfecting agents. Solutions of these salts have, in fact, he large scale for this purpose by Mr. Condy. Putrid water apidly deodorised by these solutions. Their freedom from uous character render them available for many purposes for cannot be used, as for application to wounds and fœtid advantageously used for the purification of tainted provi-, their fixed character renders them less adapted for purifying n the hypochlorites, which evolve a gas capable of acting on air. (See Hofmann's *Report on Chemical Products and nal Exhibition of* 1862.)

ative manganic hydrate (p. 810).

BONENSIS. The tree which yields the so-called Dika

EL. See BETA (i. 582). On the changes which take place plant during its growth, see R. Hoffmann. (Bull. Soc. 393.)

$C^{29}H^{22}O^5$. (W. Schmid, Ann. Ch. Pharm. xciii. 83).—A sub-sk of the fruit of *Garcinia Mangostana* (ii. 771). To obtain d with water to extract tannin, then treated with hot alcohol, t is left to evaporate, whereupon it deposits mangostin as a ice, mixed with a large quantity of yellow amorphous resin. whole is dissolved in alcohol, and the solution is mixed with it opalescent; it then, on cooling, deposits, first the resin, in small yellow laminæ. For further purification, the alco-ated with basic acetate of lead; the washed precipitate is decomposed by sulphydric acid; the filtrate is mixed at the till it becomes milky; and the mangostin which separates nally purified by crystallising it several times from dilute

d forms thin golden-yellow laminæ, destitute of taste and 190°, without loss of water, to a dark-yellow liquid, which mass; by a stronger heat, the greater part of it is decom-ming unaltered. It is insoluble in *water*, but dissolves easily forming neutral solutions. Warm *dilute acids* dissolve it ating with strong *nitric acid*, it is converted into oxalic acid. llow or brownish colour. It reduces the *noble metals* from *ic chloride*, it forms a dark greenish-black solution, the colour e addition of acids. It is not precipitated by any metallic *te of lead*. The yellow precipitate thrown down from the ral acetate of lead and a little ammonia, gave by analysis (at numbers agreeing nearly with the formulæ $4C^{29}H^{22}O^5.5PbO$.

D. An acid said to have been obtained from the root of ystallises in prisms, having an acid taste, and forms, with , neutral, easily fusible salts, crystallising in nodules; but its olished. (Handw. d. Chem. v. 113.)

resin of unknown origin, resembling Copal and Dammara e most part in alcohol of 90 per cent., and melts easily, dif-of the resin of the Coniferæ. (Buchner.)

an name of the nutritious matter of *Jatropha Manihot*, from a are made in the West Indies. It has been analysed by iv. 401.)

ine juice which exudes from certain species of ash and other mell, a sweetish, slightly nauseous taste, and acts as a mild e or less nutritious.

he manna of commerce are two species of ash growing in the nd in the East, viz., *Fraxinus Ornus*, Linn., which grows in ountainous situations, especially in Calabria and Sicily; and

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Fraxinus rotundifolia, Lamarck, or *Ornus rotundifol* flowering, or manna ash, which grows in Calabria a Decandolle, it is from this latter tree that manna is chie naturally from the trees, and attaches itself to their s parent drops; but the extraction of the juice is facil summer.

The finest kind of manna is called flake manna (It is white or yellowish-white, light, porous and friabl ing a number of small capillary crystals. Its odou honey; its taste is sweet, but afterwards rather acrid.

Inferior sorts are: 1. The *Sicilian manna*, which is merce, consisting of small, soft, round fragments of a intermixed with particles of dark flake-manna: this —2. *Manna in sorts* (*in sortis*), which may be sub approaches most nearly to flake manna; and, β. *Cap* that from the district so called, but also that of Cines fatty, sticky, and hard, though clearer in appearance than which stands between the last two (α and β), but is merce.—4. An inferior kind, known as *Manna comm* province of Capitanata, on the declivities of Mount S very damp, and is chiefly consumed in Italy, and sent duction of this kind of manna amounts to more than 2

Analyses of Manna.

According to Bucholz.*		According to
Mannite . . .	60·0	Mannite . . .
Fermentable but uncrystallisable sugar, with colouring matter (purgative bitter matter?) . .	5·5	Sugar . . . . Mucilage, with some ma resinous and acid m and a small quantity of genous substance .
Sweetish gum . .	1·5	Insoluble matter . .
Gummy extractive .	0·8	Water . . . .
Fibro-glutinous matter . . .	0·2	Ash . . . .
Water and loss .	30·0	
	98·0	

There are also several varieties of saccharine exudat manna, not produced by the ash. Of these Landerer enu *laricina*, from the leaves of *Larix europæa;* also called to Berthelot, it contains melezitose (*q. v.*).—2. *Manna Pinus cedrus*. This variety is brought from Mount Le Syria.—3. *M. celastrina*.—4. *M. quercina*.—5. *M. aust resinifera*.—6. *M. cistina* s. *labdanifera*, a rare variety derived from several species of *Cistus*, and is called Ci the exudation of *Hedysarum Alkago*, a plant indigenou in the maritime districts of Greece. This manna is supp *sarum*, which covers extensive plains in Arabia and Pale produced on the plants by the browsing of sheep and by the Arabs, as well as by those who form the car According to Landerer, it is this variety, and not the pr sponds to the *mel ex aëre* of Pliny, and the *humor melleu tamariscina*, called also *Manna Israëlitarum*, and believe mentioned in the Old Testament. He informs us that t the puncture of *Coccus manniferus*, an insect inhabiting t which grow abundantly in the neighbourhood of Mount a thick transparent syrup, covering the smaller branche collected by the monks of the district in the month of place very early in the morning, at which time, owing t saccharine juice has become to some extent congealed. in Palestine, and in the district of Sinai, as a delicacy, diseases of the chest. It is soluble in water and alco

* Jahrb. pr. Pharm. lxi. (1809). † A

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ntation. The alcohol which it yields has a peculiar odour, fruit of *Ceratonia siliqua*, which contains butyric acid. The ntain fermentable sugar, in place of mannite [or together with *Materia Medica*, 4th ed. vol. ii. [1] p. 673.) According to Ber- i. 583), the tamarisk manna from Sinai contains 55 per cent. ugar (ii. 863), and 20 dextrin, &c.; manna from Kurdistan e-sugar, 15·6 inverted sugar, and 22·5 dextrin, &c.

ee the next article, p. 825.

of Manna. Sugar of Mushrooms. $C^6H^{14}O^6$.—This substance t (Journal f. Chem. u. Phys. v. Gehlen, ii. 83), and has been hemists, including, among others, Liebig, Frémy, Strecker, enmeyer, and Linnemann. (For references, see *Gmelin's*

nd parts of plants contain mannite ready formed: the roots f celery, from *Apium graveolens;* of *Meum athamanticum;* *Polypodium vulgare;* of *Scorzonera Hispanica;* the root- m [constituting Latour's *Granatin*]; the roots of *Triticum anella alba* contains about 8 per cent. of mannite; that of ns mannite. The leaves and young twigs of *Syringa vul-* hich, mixed with *Lilacin*, constitutes Bernays' *Syringin:* also, *vulgare;* celery-leaves; the foliage of *Cocos nucifera;* the of *Cactus opuntia.* Coffee-beans contain mannite, according one year contained mannite, that of another year mycose. nite. On *algæ* there is often found an efflorescence of mannite, louse, may also be obtained from the dry algæ; according to t exist in fresh algæ, but is formed from vegetable mucilage ormed very abundantly during the viscous fermentation of or less extent during fermentation generally. In the trans- lucose by boiling with dilute sulphuric acid, it is also formed Finally, Linnemann (Ann. Ch. Pharm. cxxiii. 136) has of sodium-amalgam on glucose.

pared from manna, which is treated with boiling alcohol, and wed to crystallise. On cooling, mannite is deposited. It is on, and appears to be very easily obtainable in a high state

thin four-sided prisms, which sometimes grow to a consider- haracteristics of mannite is the ease with which it may be tion in water or in alcohol. The crystals contain no water but very slightly hygroscopic.

te dissolves in 6½ pts. of *water.* At 15°, 1 pt. of mannite *cohol* (specific gravity 0·898), and in 1,400 pts. of absolute l, it is much more soluble. In *ether*, it does not dissolve at all. f mannite does not become syrupy on being spontaneously ct it differs strikingly from a solution of sugar. It is only . It does not exert any action on polarised light.

gar in its power of resistance to the action of heat. It melts at about 200° it begins to boil, and may be distilled with even at the ordinary atmospheric pressure. In sealed tubes ° without suffering much decomposition; at higher tempera-

ept under very unusual conditions. It does not reduce oxide uboxide; but hinders the precipitation of sulphate of copper ng the formation of a beautiful blue-purple solution instead. olution of potash without imparting a brown colour to the

nnite was determined some years ago by Liebig, who fixed s at present admitted; but, as was shown a short time ago urgh, 1861–62; Ann. Ch. Pharm. cxxiii. 372; Chem. Soc. J., e been by accident; for, until quite recently, nothing was ch could lead to the adoption of one rather than another of h of them equally probable.

sting between mannite and glycerin was shown by Berthelot *sur la Synthèse*, par M. Berthelot), who obtained a great e by heating a mixture of mannite with different acids to a 200° and 250°: nitro-mannite, which is really the nitrate of

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the series, had been previously discovered by Flores Dor
then investigated by Strecker.

The connection between mannite and the hexylic grou
Erlenmeyer in 1861, by the conversion of mannite int
hydriodic acid:

$$\underset{\text{Mannite.}}{C^6H^8(HO)^6} + 11HI = C^6H^{13}I +$$

By this transformation the formula of mannite, which
was fixed with certainty.

The chemical character of mannite is that of a polyat
alcohol:

$$\left.\begin{matrix}(C^6H^8)^{vi}\\ H^6\end{matrix}\right\}O^6 : \text{type} = \left.\begin{matrix}H^6\\ H^6\end{matrix}\right\}O$$

Or, it may be regarded as hydride of hexyl in which 6
replace 6 atoms of hydrogen:

$$C^6H^8(HO)^6 : \text{type, } C^6H^{14}$$

It is closely related to the sugars, glucose becoming
nascent hydrogen, whether that hydrogen be a product
of sodium-amalgam on water:

$$\underset{\text{Glucose.}}{C^6H^{12}O^6} + H^2 = \underset{\text{Mann}}{C^6H^1}$$

Glucose is probably derived from the hydrocarbon C

On being heated to a temperature of 200°, mannit
mannitan (Berthelot):

$$C^6H^{14}O^6 - H^2O = C^6H$$

This conversion seems to be partial. Mannite is lik
by prolonged boiling with strong hydrochloric acid.

When mannite is oxidised with *nitric acid*, it is co
and not into mucic acid: on pushing the oxidation furt

Fusion with *caustic potash* causes disengagement of h
mate, acetate, and propionate of potassium. Distilled
acetone.

With *fuming nitric acid*, or better with a mixture of
gives nitro-mannite, $C^6H^8(NO^2)^6$.

With *sulphuric acid* it gives a coupled acid, sulpho

$$(C^6H^8)^{vi}H^2O^6.(SO^2)^3H^2O^3$$

Heated for some hours to a little over 200° with org
bear a considerable resemblance to the fats. (Berthe

When it is heated with *bromide of ethyl* and potash,

According to Berthelot, when it is kept for several we
and *cheese*, or other protein-compound, at a temperature
carbonic, lactic, butyric and acetic acids, and hydrogen:
production of yeast, and no fat, nor glycerine nor sugar.
as a ferment, then there is production of sugar.

Inasmuch as glycerin has been produced artificially
viz., from $C^3H^5Br^3$, there is reason to expect that manni
tive of hexylene. Up to the present time, however, the
been realised.

Salts of Mannite.—In Berthelot's *Chemie organiq*
salts of mannite are described, *i. e.*, acetate, butyra
stearate, oleate, benzoate, and tribenzoate. They are
mannite or mannitan with the acid to a temperature r
for from 12 to 15 hours. At the end of this process m
In order to purify the salt, the crude product is trea
(baryta or carbonate of sodium) which combines with t
up by the mannite or mannitan, but does not attack th
produced. Ether is then added and dissolves the salt.
evaporated, yields the salt, which is an oil or a fat acco

Of the salts above mentioned the butyrate appears to
in all cases only a portion of the mannite or mannitan
salt. There is the closest resemblance, both physicall
salts of glycerin and these salts of mannite.

Berthelot regards these salts as derivatives, not of man
$C^6H^{12}O^5$. Their formulæ (given under Ethers, ii. 521)

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Derivatives of Mannite.

= $C^6H^{14}O^6 - 2H^2O$.—Discovered by Berthelot, who obtained
with butyric acid. It constitutes a syrup, which is at first
terwards bitter. It is very soluble in water and in absolute

ance connected with it is its volatility. It is sensibly volatile
apidly at 140°.
nt, passing gradually into mannite when it is exposed to a
posed in an open vessel to the air in the usual state, it
r cent. of moisture, whilst in air saturated with moisture, it
much as 80 per cent.
her, but a derivative of the hydrocarbon C^6H^{10}, viz.,

.—Discovered by Berthelot. Obtained, but only in small
nite to about 200°. A better method of preparation is by
of mannite with strong hydrochloric acid; or by the saponifi-
te. It is a curious fact, that the salts of mannite always
ification, the mannitan passing subsequently more or less

with a slightly sweetish taste. It may be very readily
te by its solubility in absolute alcohol, which thus affords a
ration of these two substances. It is very soluble in water,

length of time to the atmosphere, it undergoes a very partial
Boiling with alkalis or dilute acids accelerates this change.
0°, it partly volatilises.
ional constitution, it appears to the writer of this article that
r of mannite. It would seem rather to be derived from a

being derived from C^6H^{14}, *i. e.*, $C^6H^8(HO)^6$.
n „ from C^6H^{12}, *i. e.*, $C^6H^7(HO)^5$.

ylic compounds pass into hexylene is again encountered in the
ch are hexyl-compounds that have suffered replacement of
hydrogen. (See HEXYL-COMPOUNDS.)

$H^8(NO^3)^6$.—Prepared by treating mannite with the strongest
acid. It forms beautiful fine white acicular crystals, insoluble
lcohol or ether. It explodes very violently on being struck
If carefully heated, it may be decomposed without explosion;
heated, it explodes, but not with great violence. It seems to
position on being kept for a long time.
to use nitro-mannite for charging percussion-caps, but
ss.
nnite which is of considerable theoretical interest is that with
by which reagent it is converted, not into a nitrogenous
nnite.

id ($C^6H^{14}O^6 3SO^3$). A kind of mannite-sulphovinic acid, is
f strong sulphuric acid upon mannite. A barium-salt,
er salts of this acid, have been obtained. J. A. W.

. $C^6H^{12}O^7$.—An acid produced, together with mannitose, by
under the influence of platinum-black; it was first observed
e completely investigated by Gorup-Besanez (Ann. Ch.
prepare it, mannite is mixed with twice its weight of pla-
xture, moistened with water, is exposed to a temperature not
he utmost, as long as it contains any undecomposed mannite
or 30 grains of mannite). The mass is then exhausted with
pitated with basic acetate of lead; the well-washed precipi-
hydric acid; and the solution is evaporated, first over the
ld over sulphuric acid.
ystallisable, but forms a gummy mass, soluble in water and
ble in ether. It reduces cuprous oxide from an alkaline
s down metallic silver from the nitrate.
e not yet been obtained in the crystalline form. The compo-
d by Gorup-Besanez corresponds with the formula $C^6H^{10}M^2O^7$.
a^2O^7, is precipitated from its aqueous solution by alcohol.
O^7, remains as a green amorphous mass when its aqueous

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solution is evaporated. The *lead-salt*, $C^6H^{10}Pb''O^7$, separ tion obtained by boiling mannitic acid with lead-oxide. separates as a greenish-yellow precipitate on mixing a calcium-salt with nitrate of silver.

MANNITOSE. $C^6H^{12}O^6$.—A kind of sugar, isom together with mannitic acid, in the oxidation of mannite u black (Gorup-Besanez, *loc. cit.*). It is fermentable, light. It exhibits, with alkalis, alkaline cupric soluti carbonate of sodium, and other reagents, the same behavi but does not unite with chloride of sodium; its alcoho holic potash containing 11·27 per cent. potash, forms corresponding with the formula $K^2O.2C^6H^{12}O^6$. (Gme

MANURE. *Dünger. Engrais.*—This term, in its cable to any material used in agriculture and horticult the effect, of accelerating vegetation, or of increasing the p In a usual and more limited sense, it signifies the accu ings, stables, and cattle-yards of a farm—including anim plants, &c. (See Voelcker, 1856–9, *Journal of the E England*, xvii. 191; xviii. 111; xix. 112; xx. 134; O yard Manure.—Lawes, 1862 *ibid.* xxiii. 45.) Burnt are also commonly used as manure.

In addition to these kinds of manure which are pro result of its internal economy, or obtained in the immedi to which they are applied, a variety of other materials ar pose, under the name of *artificial manure*. These mate the farmer from extraneous sources, and sometimes from ing to their value. They comprise guano (ii. 952), bones minerals (Apatite, i. 348; Coprolites, i. 82), ammonia- slaughter-houses and of various manufactures; fish, sea-w in the form either of night-soil or sewage; and artificial *Dictionary of Arts, Manufactures, and Mines*, iii. 36 *et s Roy. Agric. Soc. Eng.* x. 196—Composition and Value of On Superphosphate of Lime, 1856, *Ib.* xvi. 533—Valu Voelcker, 1861–2, *Ibid.* xxi. 350; xxiii. 277—Chemic cial value of Phosphatic Manures and Artificial Manures.

The fertilising influence of manure is a fact which has experience wherever the cultivation of plants has been considered as that branch of industry which is concerne for man and domesticated animals, and therefore the m life—manure may be regarded as being, to a great extent A complete knowledge of the causes to which the efficacy mode in which it acts, would comprise the whole chemist management of the manure naturally resulting from s basis on which rests the profitable practice of the art, the should regulate all the operations of the farm, and deter only by means of such knowledge that it can be possible method of culture, or to make a right selection and use o natural manure of the farm, with the object of augmentin land, by rendering effective, in a higher degree, the natur

The principles involved in the action of manure are to that knowledge of the general phenomena of vegetati chiefly within the present century, and has begun to as only within the last five-and-twenty years. The dat ledge is founded were contributed chiefly by the successi Ingenhousz, Sennebier, Woodhouse, Saussure, they afforded materials for a view of the chemistry of v that which considered decaying animal and vegetable sub plants, they were but little regarded; and though the re conducted with special reference to agricultural practic plant-nutrition held its ground, and was adopted by D "Elements of Agricultural Chemistry," delivered befor between 1802 and 1812. In those lectures he did little problem to be solved in the application of chemistry to ag important relation between the science and the art; but illustrations of the correct appreciation of natural facts w genius. (Priestley, 1772, *Phil. Trans.* 72; lxii. 157 *Experiments on Vegetables, &c.*; 1782 *Phil. Trans.*; 17

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1798, *Essay on the Food of Plants and the Renovation of*
1792, *Jour. Phys.* xiii., xiv. Sur la Nutrition des Végé-
Trans. Roy. Irish Acad. v. 123. What are the manures most
e to various sorts of soils, and what are the causes of the bene-
instances?—Sennebier, 1800, *Physiologie végétale, &c.*—
holson's Journ.—Saussure, 1804, *Recherches chimiques sur*
Collected Works, vii., viii.)

k of Saussure's researches, Boussingault entered upon
bject, conducting his experiments on a much larger scale, and
on to agricultural practice than had hitherto been attempted.
was also led, by the suggestive work of Saussure, to study
thy and saline substances upon the growth of different plants,
n have been continued to the present time. Boussingault's
ect were published in 1836, and in the year 1839 he had made
estigations, which—besides establishing the composition of
s of agricultural produce; the efficacy of various materials in
general relations between the composition of the crops obtained
he ordinary routine of practice in his locality—had led him to
at the carbon and nitrogen obtained in the several crops com-
nted to much more than was contained in the manure supplied
nd consequently, that those constituents must be derived in
osphere during vegetation; that those alternations of crops
mulations of carbon and nitrogen being gathered from the
ed upon the farm most largely, in the form of manure, were
that certain plants were better fitted for this purpose than
ue of manure was, to a great extent, indicated by the amount
which it contained. (See Boussingault, 1836, *Ann. Chim.*
la quantité d'Azote contenu dans les Fourrages, et sur leur
4, 1838, lxvii. 408-421; Examen comparatif des Circonstances
quelles végètent certaines Plantes alimentaires, à l'équateur et
337-358; 1837, Des Influences météorologiques sur la Culture
Mémoire sur la quantité de Gluten contenue dans les Farines de
nent cultivées dans le même sol, lxv. 301; De la Discussion de la
ments par l'analyse élémentaire, *Compt. rend.* vii. 1149; viii. 54.)
aussure had already adopted the opinion that the carbon of
ent, derived from the atmospheric carbonic acid; and the same
d by Brongniart, in reference to the origin of the coal strata,
he humus theory. (Brongniart, 1837, *Compt. rend.*, Con-
re des Végétaux qui ont couvert la surface de la Terre aux
rmation, v. 403-415.)

the year 1840 that a comprehensive theory of plant-nutrition
ebig, with such perspicuity and force as to excite universal
ental proposition of that theory was, that the food of plants,
the chief mass of their substance is produced in vegetation, con-
cid, water, and ammonia. The chemical arguments by which
, in opposition to the prevailing opinion, that plants derived
oxygen, and nitrogen from humus, and from other vegetable
were conducted in such a convincing and logical manner, that
lly regarded as being entitled to the same honour in the
eory of plant-nutrition, as if the data on which it was based
l with himself. Liebig's researches on the phenomena of the
table materials afforded, together with the existing knowledge of
l life, the most conclusive evidence that the ultimate products of
rbonic acid, water, and ammonia, precisely those materials
od of plants. Moreover, these substances cannot be com-
as not to contain a far greater amount of oxygen than the
nts collectively consist, and which are produced in vegetation.
elimination of oxygen was a necessary feature of vegetation,
w light upon the known constitution of the atmosphere and
rbonic acid by growing plants; at once establishing a most
een the phenomena of vegetation and of animal respiration, and
al interdependence of the processes of animal and vegetable life.
he food of animals is provided exclusively by the vegetable
in the form of corn, roots, fruit, &c.; or indirectly, through
ife, as the flesh of herbivorous animals, the importance of a
stry of vegetation, in reference to the cultivation of plants as
nals, is self-evident. Consequently, Liebig's exposition of

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his theory of plant-nutrition had especial reference to the
as the researches of Saussure, Boussingault, Lawes,
cuted in the same direction; and it was developed, in its appli
culture. (Liebig, 1840, *Chemistry in its Applications to A*

In order to illustrate fully the chemistry of manures, an
their use, as well as in the general routine of agricultural p
to give a brief statement of the general features of the ch
sidered from an abstract point of view, so far as the presen
will permit; then to describe the conditions which exer
influence upon vegetation, in regard to the object appertaini
and the different means adopted for the attainment of th
modification it receives by the various special circumstan
practised.

The ultimate result of the growth and development of
duction of a number of oxygenated and nitrogenous hydroc
sugar (ii. 855), gum (ii. 953), lignin (i. 818), fat (ii. 61
(ii. 873), legumin (iii. 568), fibrin (ii. 643), &c., which, in
modification, are universal constituents of all plants; an
analogous substances, which are special constituents of part
plant-organs.

The chief mass of the solid portion of plants consists of
main function of vegetation to produce them, and thus to
(See Nutrition.)

These constituents of plants were formerly termed, in a
substances, in conformity with the opinion that they coul
plant-organism, under the influence of vital action; and tha
in their chemical nature, from the compounds producible
belonging to the mineral kingdom, which were termed "ino
chemically from the proximate constituents of organise
animals—and from the derivatives of those compounds. I
has discarded that opinion, and with it the use of the term
expressive of a distinction which no longer represents a
the term "organic" is still conveniently applied to the
animals without involving such a distinction. (Gerhar
organique, i. 1–6.)

The materials from which the proximate constituents of
tation are few. According to the present state of knowledg
cipal source of the carbon; but in the case of some plants,
may possibly be derived from other carbon-compounds. (See
Water is the source of hydrogen and oxygen, while nitrogen
monia; to some extent also from nitric acid; possibly from
logous to humus, and from the elementary nitrogen of th
directly or indirectly, or even at all, has not been ascertai
evidence is in favour of the opinion that elementary ni
milated by plants. See on this subject: Saussure, 180
Collected Works, vii., viii.;—Boussingault, 1838, *Ann.*
lxix. 353–367; Recherches chimiques sur la Végétation, e
aminer si les Plantes prennent de l'azote à l'atmosphère,
xliii. 149–223; 1856, xlii. 1–41; 1858, *Compt. rend.* xlvii.
129; 1839, vii. 889.—Liebig, 1840, *Chemistry, &c.*—Mu
of Vegetable and Animal Physiology.—G. Ville, 1853, *Re*
tation; 1856, *Compt. rend.* xlii. 679; xliii. 85, 143, 612.—
xxxii. 180, 770.—Roy, 1854, *Compt. rend.* xxxix. 1133
1850–5, *Compt. rend.* xli. 775, 935.—De Luca, 1856,
Harting, 1855, *Compt. rend.* xli. 942.—Petzholdt, *J.*
Lawes, Gilbert, and Pugh, 1862, On the Sources of N
Trans. for 1861, p. 431 *et seq.* and, 1863, *Journ. Chem. S*
Physiological Chemistry, Cavendish Soc. iii. 178.—Mol
Henfrey, pp. 77–88.

Among the substances above named, carbonic acid, wat
the chief materials of plant-food; and since it is from the
ents of plants are principally produced in vegetation, they
the "organic materials of plant-food" (*Quarterly Review*, l
Plant, p. 173). Under natural conditions, these substance
plants by the atmosphere (i. 437–439), which contains them
large aggregate quantity, continually replenished by the
Respiration); by the decay of dead animals and plants

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omena of the mineral kingdom (i. 770, ii. 835); by industrial and (Combustion, i. 1095; Fuel, ii. 722); by rain, dew, and the r from the ocean, lakes, and rivers (see Water and Ammonia, erial whether these substances are supplied to plants exclusively by hether they are derived from other sources as well; in either case rd to vegetation is the same. They may, therefore, be termed ood of plants; and the organic substances produced from them in esignated the air-derived constituents of plants. So far as relates t view of the chemistry of vegetation, it is a matter of indifference ls, constituting the air-food of plants, are derived exclusively and nosphere, or whether they are to some extent derived from other irectly; as, for instance, by the decay of humus or nitrogenous substances contained in the soil, or supplied to it as manure. The ever, when vegetation is regarded from a practical point of view—ucing food for animals artificially—and when the objects and cir-actice of agriculture have to be included in the consideration of erence is of the highest importance.

other materials concerned in vegetation besides the carbonic acid, from which the plant constructs its chief substance. In almost ry organ of a plant, there are certain substances—indestructible n as ashes when plants are perfectly burnt. (See Ash, i. 416 *et seq.*) ants contains potash, soda, lime, magnesia, phosphoric acid, sul-on, &c., which, in the case of land-plants, are derived exclusively h the plants grow. The relative proportions of these substances different plants, and in the different organs of the same plant; gh in a less degree, according to the character of the soil on which most of them are, in greater or less amount, constant constituents refore to be regarded as necessary to their existence and essential Kirwan, 1794, *op. cit.* 145, 148– Saussure, 1804, *Recherches tation*, pp. 261, 269.)

the chemistry of agriculture, these substances have been commonly ' or the "inorganic" constituents of plants; mineral,* in accor-nised classification of natural objects, into mineral, vegetable, and are earthy in their nature, and are likewise derived from the earth: ish them from the organic constituents of plants, which are pro-rom carbonic acid, water, and ammonia. (H. Davy, *Elements of y*, 1827, Collected Works, viii. 40, *et. seq.*; Liebig, *Chemistry in riculture and Physiology*, 1840, p. 92. *et seq.*)

which the above substances are found in the ashes of plants is nt from that in which they exist in the plants themselves, and s to what that may be. The functions they perform in vegetation

et "mineral" to denote those constituents of plants which are not dissipated nguish them from the other constituents, and from other materials of plant-r, and ammonia—has recently been objected to by a high chemical authority, re, indicating confusion of ideas, since the epithet "mineral" applies "equally volatile and fixed, of plant-food" (Hofmann, *Chemical Products and Pro-hibition*, 1862, Class II. Section A, *Reports by the Juries*, p. 159). Since the s a subject concerning which it is especially desirable that any real or supposed ms, or of ideas, or of facts, should be stringently eradicated, and kept clear of, hat authority, abstain from such use of the term "mineral," substituting for it e those constituents of plants which, being earthy, are derived exclusively from the same rule in reference to the materials of plant-food which are supplied order to distinguish them from the other materials of plant-food—carbonic . In doing so, however, I may remark that the use of the term "mineral," has long been common among chemists; and will venture to suggest that there ience to authority, for abstaining from that use of the term which has been cus-epithet "mineral" unquestionably does apply "equally to *all* the elements, plant-food," still it does so only in a Natural History sense, not as synonymous inorganic," when used in its true sense as the antithesis to "organic." Nor mineral," in special reference to the chemistry of agriculture, been such as to o, or confusion with, the term "inorganic," when used in its true chemical the term "mineral" has been used in reference to that subject, during the last e specific designation of the ash-constituents of plants; and during the last those substances from the other "inorganic" materials of plant-food—carbonic . This is aptly illustrated in "*An Address to the Agriculturists of Great Britain, and Use of Artificial Manures*, by Professor Justus Liebig—Liverpool, 1845, "They are mineral substances, and as such, are indestructible by fire; and, ashes after the incineration of the plants, or of their parts." (See also . 173.) In fact, the term "mineral," so used, has a real advantage, in being m "inorganic," also used, in some instances, by Liebig and others, for the fixed, ash, or soil-constituents, as contradistinguished from the other materials acid, water, and ammonia—which, in a chemical sense, are also "inorganic," ly been called the "organic" materials of plant-food (See Liebig, 1840, *ons to Agriculture and Physiology*, pp. 3, 92, 114.—Boussingault, 1845, *Rural erly Review*, 1842, lxix. 336, *et seq.*—Lawes and Gilbert, 1847—64. *Journ.* xii. xvi. xvii. xviii. xxi. xiii. &c.—B. H. P.

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are also little understood. The amount of them contain very small; but those which are constant and essential co being necessary to vegetation, must be regarded as indisp food. (See Kirwan, *op. cit.* 149, 157—Saussure, *op.* from the fact that plants will not grow to maturity und supply of the ash-constituents found in them under c necessity of the ash-constituents in vegetation is rendered fact that the fluids and organs of animals contain pre which are always found in fully-developed plants. (Bone, i. 619; Chyle, i. 961; Flesh, ii. 663; Gastr tissue; Nervous tissue.)

Moreover, the functions of these ash-constituents in th been so far traced, that there cannot be any doubt of thei the growth of animals—when they partly remain in t increase—and during the life of mature animals, when th cumulate in the body, but are eliminated, either direc with the rest of the daily food, in the excretions, after in the chemical process of animal life. (See Nutrition.)

The ash-constituents of plants have, therefore, a two-fold concerned both in vegetation and in animal life. Since the atmosphere, it is evident that the soil on which plant tant share in vegetation than that of affording merely m likewise the source of an essential portion of their food.

The mode in which the materials of plant-food are t the plant is twofold: partly by means of the leaves, a absorption of carbonic acid by the leaves and green part Priestley (1772, *Phil. Trans.* lxii. 166), and more fully de Sennebier, is one means by which plants may appropriat but whether they obtain nitrogen in the same way, has *The Vegetable Cell*, p. 86). The ash-constituents of plant organism only by the roots, and the structure of plants j are taken up in the state of solution in water (Mohl, *op.* ash-constituents, other food-materials are taken up by tivated plants—carbonic acid, ammonia, or other nitro from the decomposition of humus, and perhaps also carbo carbonic acid. (See Mohl, *op. cit.* pp. 80, 81.—Mulde *and Animal Physiology*, pp. 142–188.—Trinchinetti, *Radici*, pp. 55.—Boussingault, *Rural Economy*, p. 41

Scarcely anything is known as to the precise influenc and development of plants by the relative amounts of a sphere and from within the soil, or of the modification from such influences; though there are numerous fact experience, which apparently indicate that this circumstan importance in determining the character of the produce.

Nor are the special functions of particular materials plants any better understood, though experience appears ful in some other way than by directly contributing to plant; and it is far from being established that either th stances of which plants consist afford a quantitative ind which are necessary in their growth. This is especially th which are frequently grown with special objects, requirin ment of particular organs and constituents.

These circumstances render it very doubtful whethe during their growth, can be correctly measured by a kn alone, any more than it would be possible, in the case quantities of food required during their existence, mere qualitative and quantitative composition of the animal at

The various materials concerned in vegetation as plant- for the growth and development of the great majority of be replaced by anything else, not even by an increased a All must be supplied together; in the absence of any one are wholly incapable of supporting vegetation, and defi effect of the remainder.

However, the relative proportions of the several materi vegetation, are not absolutely constant for all plants: on t extent for different plants, or families of plants: some upon the air-food than others; some requiring a greater p

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produce the nitrogenous constituents in larger proportion
produce chiefly the corresponding non-nitrogenous constitu-
some require alkalis, some phosphoric acid in preponderating
iefly lime, silica, &c.

under which plants grow also exercise a considerable influence
ements as regards the several food-materials, and in deter-
ular organs, as well as the relative proportion of the nitroge-
s constituents produced. Many plants become, under culti-
oth in structure and composition, from what they are in a
on; but the extent to which this influence is, or may be
sufficiently known, nor are the conditions which determine it
e and season, the physical condition of the soil, the greater or
me or all of the food-materials may be obtainable by plants
e copious or scanty supply of certain food-materials, are all
is respect, and this subject still offers a wide field for obser-

s of vegetation which are neither chemical nor climatic, the
ate of land exercise great influence upon the amount of pro-
lly, in this respect, according to the relative proportions of
ich they contain, and they differ, perhaps still more widely,
ey possess, or are capable of acquiring by tillage. (See SOILS,
5, *Rural Economy*, pp. 258–308.)

al conditions of vegetation consist then, in a supply of food-
the existence in the soil of the requisite ash-constituents in
ion by plants. and a supply of the requisite air-food.
s obtain in due proportion, together with the conditions of
particular plants—whether perennial or annual—those plants
, and perfect development.

o the purely chemical conditions of vegetation, other condi-
quantity of plant-substance produced within a given time
the amount of produce—will be determined, within certain
plant-food supplied; and it will be limited by the available
nt of the food which is supplied meanwhile, in least amount,
equirements of the particular plant growing.

differences recognisable in vegetation at different places, or
ifested in the unequal amount of produce, cannot be ascribed
of air-food, which is always constant, and everywhere the
to seek in the soil for the chemical cause of these differences
s represented by the amount of produce. The soil being the
stituents of plant-food, the capability of performing its share
s of vegetation must necessarily depend upon its containing
nts, in sufficient amount, and in such a state, as to be avail-
ts.

hat soils have been formed by the mechanical and chemical
ssing the most varied composition, that they consist of the
nite, basalt, clay-slate, limestone, sandstone, chalk, &c., it is
l constituents must vary very considerably according to the
they have originated, just in the same manner as they differ
, loamy, or argillaceous.

ash-constituents concerned in vegetation will therefore be very
Moreover, the different chemical nature of the minerals consti-
soils have originated, and the unequal susceptibility of those
under atmospheric influences, give rise to wide differences
o the chemical condition the ash-constituents they contain.
may influence the fertility of land.

ons of tillage, besides communicating to soils that texture
it of the free development of the roots, are also conducive to
minerals in the land, by facilitating the access of atmospheric
decomposition of insoluble alkaline silicates. The fertilising
land, especially when it contains a large proportion of clay,
it was at one time believed to be a substitute for manuring.

ndry.—Smith, *A Word in Season: Lois Weedon Husbandry.*
om which so much advantage was at one time anticipated,
ful as had been supposed in regard to agriculture, or, indeed,
trustworthy indication as to the composition of soils or their
statement of the most prominent features of a number of
several chemists under the direction of Magnus, will serve to

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give some idea of the variation affecting the most import
acid and potash, &c., existing in such states as to be so
hydrochloric acid. (Magnus, 1846, *Ann. der Landwirth*
Versuche betreffend die Erschöpfung des Bodens, welc
Oekonomie-Kollegium veranlasst hat.)

	Percentage amount of ash-constituents			
	Soluble in dilute acid.			Insol
	Average.	Maximum.	Minimum.	Maximu
Lime . . .	0·895	. .	. .	. .
Magnesia . .	0·260	. .	. .	. .
Potash . .	0·221	0·530	trace	3·40
Soda . . .	0·161			
Silica . . .	0·448	. .	. .	. .
Phosphoric acid .	0·172	0·651	trace	. .
Sulphuric acid .	0·154			
Ammonia . .	. .	.	. .	. .

The extent of the resources of land in ash-constituen
by the following table calculated from the results of exper
and Gilbert at Rothamsted, in which wheat was grown
without any manure for 20 years. The land was a heav
The average amount of produce in the neighbourhood at
ments were commenced was under 22 bushels per acre,
once in five years. When the experiments were commenc
such a condition that, according to the ordinary routin
manured with farm-yard manure: for since the previous
crops had been removed from it, viz. barley, peas, wh
Gilbert—1847—*op. cit.* viii.—Agricultural Chemistry-
of Experiments on the Growth of Wheat—1857—*Chem.*
Points in the Composition of Wheat Grain; its Products i

	Ash-constituents removed			
	In 20 consecutive years.			
	Total produce.	Corn.	Straw.	
	lbs.	lbs.	lbs.	
Total ash-constituents .	2241·00	354·00	1887·00	1
Silica	1229·77	3·54	1226·23	
Phosphoric acid . .	252·56	177·10	75·46	
Potash . . .	360·94	106·26	254·68	
Soda	9·43	. .	9·43	
Lime	105·49	11·16	94·33	
Magnesia . . .	77·40	39·67	37·73	
Sulphuric acid . .	51·88	. .	51·88	
Chlorine . . .	37·73	. .	37·73	

The soils in which the fertilising effects of tillage are m
a clayey nature, and are therefore capable of furnishing a
tuents under the influence of atmospheric decompositio
characteristic which such soils possess in a high degree, viz.,
ammonia from the atmosphere. (See Faraday—1825—
xix. 16 *et seq.*) By reason of this capability, they store up,
the ammonia conveyed to them from the atmosphere by ra
provide an increased supply of this air-food to plants requi
Gilbert, *Op. cit.* xvii. 293 *et seq.*)

The absorptive power of soils is not limited to ammon
most of the important ash-constituents of plant-food which
fact was first observed by Thompson (1850, *Journ. Ro*
xi. 68), and was afterwards investigated by Way (*Ibid.*

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condition in which substances are thus retained by soils, so
ed to the roots of plants by the medium of carbonic acid and
nce in regard to the nutrition of plants, and to the relative
ns; Way and Voelcker, *Op. cit.*; Liebig, *The Natural*
et seq.)

aical conditions which determine the relative fertility of land,
xamine, in the first place, how far this is determined by the
as these alone are concerned, the degree of fertility of land
uting to the growth of a greater or less amount of produce—
emical sense, proportionate to the available amount of ash-
e of furnishing within the period of growth; but the amount
ry in the same ratio, because the ash-constituents of land
ation, except in so far as they can co-operate with a due

food, available during the period of growth, were limited
ic supply, the amount of produce would be proportionate to
ion by the plant, under the other prevailing conditions of

ir-food were available within the period of growth, in addition
, and together with an abundant supply of ash-constituents
produce would be largely augmented under conditions other-

on land affording only a scanty supply of available ash-con-
nat account, incapable of assimilating air-food to the full
supply, and the amount of produce in such case would be
nd decay of these plants, their ash-constituents would be
to become capable of serving for a succeeding growth of
of humus, at the same time, would provide in the soil itself
d in addition to the atmospheric supply. Still the amount
ding growth would be small, if the available supply of ash-
scanty as before. In this way vegetation might continue in-
ion, affording sustenance to numerous animals, as in the
ne prairies and pampas of America.
of ash-constituents became available, in the interval between
the decomposition of minerals in the land, the conditions
ensure assimilation of air-food not only to the full extent of
ring the period of growth, but also from the further supply
decomposition of humus in the soil; and in such case the
be proportionally increased.
unt of available ash-constituents is, therefore, not the only
amount of produce or the fertility of land depends, even in
another essential condition is the amount of air-food capable
thin the soil, during the period of growth. Land, however
stituents—however well adapted in all other respects for
still afford but scanty produce without an ample supply
riod of growth. The increased supply of air-food provided
humus in the soil may be regarded, in this respect, as the
supply of several successive periods of growth; and the capa-
uch a supply is, in a chemical sense, as much an element of
e amount of ash-constituents it contains.
fferent plants for such an augmented supply of air-food, in
produce, differ very widely, and the capability of different
ir-food thus stored up is also very different. The adaptation
ant, in this respect, to provide for the requirements of another,
h that view of particular habits and conditions of growth
, constitute the basis of the modern system of agriculture.
ed the general features of the chemistry of vegetation, in its
now be considered in their relation to agriculture; and it will
ine the conditions affecting the supply of ash-constituents, as
der different circumstances.
lants as a source of food for animals, and for other purposes,
isite for vegetation are removed from the land in the produce;
placed in the same manner as the atmospheric supply of air-
th of a particular plant, year after year, would in process of
and of available ash-constituents, as to render it incapable of
th, or of yielding such an amount of produce as would be

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worth the trouble and cost of cultivation. Hence arises
returning to land under cultivation the ash-constituen
Hence the practice, intuitively adopted in the rudest stat
to land the excreta of animals fed upon its produce and
plants grown upon it. Such a system of cultivation woul
decrease in the annual produce of the land, inasmuch as
manure, would restore whatever had been removed in th
animals, or for other purposes, and thus render the land
the aid of the atmospheric sources of plant-food—to suppor
Op. cit. p. 160.)

If there were absolutely no export of produce, in such
ash-constituents would be complete, and the capability o
undiminished, so far as relates to the ash-constituen
increase year by year, so far as ash-constituents were c
amount of them would be gradually increased by tillage, a
position of minerals in the land. The improvement of th
referable in some degree to such an unlocking of its natur
of what may be regarded as its floating capital in ash-cor

Where the population of a country is small and thinl
is of little value, as in many remote and uncivilised locali
fulfilled by such a system of relying upon the natural pro
effort to increase it. But, even in such circumstances, it is
ditions of fertility are relied upon exclusively, or that the
ing the amount of produce are limited to the internal eco
fertilising materials can be obtained from external sou
with their capability of augmenting the produce, are gener
in the rudest practice of agriculture. Guano has long b
the natives of South America (Humboldt, Fourcroy,
Chim. lvi. 258–268). Fish, seaweed, &c., have been us
manure by the peasantry of seaboard districts; and woo
applied to the same purpose inland. Most of these mater
of available ash-constituents in the land, and would in
of production.

Where, on the contrary, the population of a country wa
tres, and a portion of the corn grown was annually remove
of food to towns at a distance, or under circumstances no
ing excreta being returned to the land as manure, t
deprived of ash-constituents, in a degree proportionate to
ternal economy of the farm would then no longer ensure th
of all the ash-constituents of its produce; it would no long
the degree of fertility obtaining before the export of th
capability of production corresponding to the amount of as
tained in the land. On the contrary, as the yearly expo
tion of ash-constituents from the land progressed, the c
them and the atmospheric conditions of vegetation at any
changed; for while the atmospheric supply of air-food re
of ash-constituents in the soil would diminish from y
vegetation might be no longer possible, in consequence of
essential conditions.

Even before that time, a point would be reached when
be no longer limited by the supply of air-food available
the period of growth; when, on the contrary, the assim
limited by the available amount of ash-constituents in th
of produce would be so small as not to be worth cultivati

This exhaustion of land, or reduction of the degree
successive corn-crops, and by the export of the produce, w
from extraneous sources, would take place sooner or lat
the land and the extent of its natural resources; sooner
known as light land, than in the loamy or clay soils, kno
the ash-constituents were concerned, the exhaustion of l
such circumstances, or the capability of production revive
intervals without growing a crop on it for one or more ye
the name of bare-fallow. (See Kirwan, *Op. cit.* p. 160.

During the interval of rest, a fresh supply of availa
provided for a future crop of corn by the decomposition
compensating, either wholly or in part, for the abstr
of produce. The amount of produce obtained, when a c
this way remain constant, or suffer but inappreciable di

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rich soils. The rate at which the restoration of the ratio—pre-
the supplies of available ash-constituents from the soil and of
here—took place, would depend upon the nature of the land and
termine the interval to elapse between the growth of two crops

t be attained by a rotation of crops, or the alternate growth of
ng different ranges in the soil during their growth, or requiring
ts, such as corn and grass, or potatoes; so that, in either
ts contained in the land might be distributed among the dif-
rendered available during a longer period. If the crops grown
the corn-crops were consumed on the farm in feeding cattle,
o the production of manure; and, even if some of the cattle
er part of the ash-constituents of the fallow-crops on which they
ain upon the farm, and be returned to the land in the manure.
esult of exhaustion would still be the same; and it has been
blished fact, that "the export of grain from a country, unless
becoming manure are introduced in compensation, must ulti-
the soil. Some of the spots now desert sands in Northern
were anciently fertile. Sicily was the granary of Italy; and the
off from it by the Romans is probably the chief cause of its
is island our commercial system at present has the effect of
ich in their use and decomposition must enrich the land."
—See Kirwan, *Op. cit.* p. 160.—Liebig, *Einleitung in die*
ues, pp. 106–109.)
ctice of agriculture, therefore, it is as necessary to maintain
in a sufficient amount of produce. Land from which corn is
st cases, a constant supply of manure from extraneous sources,
ash-constituents which may have been rendered deficient in

d of the extent of the exhaustion of land from which corn
that, in the countries which are the chief sources of corn,
at the rate of 15 bushels per acre, and that a corn-crop is
The quantity of ash-constituents removed from the land per
e about as shown the following table:—

h-constituents of Wheat, Barley, Oats.

	Total produce.	Corn.	Straw.
acre .	2260 lbs.	15 bushels	1333 lbs.
. .	92	15 lbs.	77
ic acid .	11	8	3
. .	14	4	10
magnesia	8	2	6
. .	51	0	51

e being contained in the straw, would be returned to the land
and if the whole of the corn were exported, without any
ts from without, there would be a permanent abstraction of
phosphoric acid and 2 lbs. of potash annually per acre. These
ch are least abundant in land, it is necessary that they should
e way.
maintain the degree of fertility, the supply from without does
o the quantity removed in the exported produce; for land
ion to its immediately available resources in ash-constituents,
latent—resources from which fresh supplies of them are only
rendered available by the operations of tillage in the manner
ante, p. 831, and Soils.)
austion of soils, in regard to ash-constituents, though con-
mstances as those above referred to, is almost inconceivable,
ry land, under circumstances admitting of a proper supply of
sources, in addition to that produced upon the farm.
ituents of land determine its share in the general conditions
garded as practically inexhaustible under any system of agri-
ed to be good merely from an empirical point of view, and
endation than success.
ce of manure is not, however, limited to the restoration of

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ash-constituents to land. It is also due to its capability o air-food to future crops, during their period of growth, t from the atmosphere. This is one of the chief advantag the growth of fallow-crops for feeding cattle. The adva some extent, due to the accumulation of air-food in the power. (See *ante*, p. 831, and SOILS.)

Since the available ash-constituents of land can be e creased amount of produce, only in so far as they can co supply of air-food, during the period of growth, it is evide dition of fertility, by manure, must be of especial impo obtain a large amount of produce.

The total resources of the generality of land in ash largely over the constant chemical conditions of fertilit atmosphere, within the period of growth of ordinary crop land so easily admit of the liberation, from time to time stituents by the operations of tillage, that, under a probability is rather in favour of the ash-constituents av being in excess of the supply of air-food directly availa within the period of growth, and of that provided by n ternal economy of the farm.

In some cases, the gradual unlocking of the latent re &c. may far exceed the yearly abstraction of ash-const dition of fertility in land may increase from year to yea constant proportion to the supplies of air-food from the it may preponderate over them; so that the amount of pro be increased, if the other chemical conditions of fertilit proportion within the period of growth. But though increase the fertility of the land, so far as the ash-co would not be attended with an increase in the amount of panied by an increased supply of air-food during that pe crop, for which the liberated ash-constituents were most

The extent to which the accumulation of available ash- may take place, is well illustrated by the experiments growth of wheat, upon land which had been reduced to su routine, as to yield only half the average amount of proc manure containing only the ash-constituents of wheat, amount of produce obtained in 1844 was not greater tha the following year, the application of 336 lbs. per acre o and chloride was attended with an increased amount of that obtained in the previous year from the unmanure with ash-constituents only. By continuing to grow wh nineteen consecutive years with ammonia-salts only as m of produce obtained in each year continued to exceed th and the average amount of produce thus obtained, duri one-fourth less than it was in the first year, notwithstan continued drain on the ash-constituents of the land. (1847-64. *Op. cit.* viii. 226 xxv.)

Manure.		Amount of Produce per A			
		Dressed Corn.	Corn.	Straw.	
		bushels.	lbs.	lbs.	
1844	Unmanured	15	923	1,120	
	Ash-constituents	15½	1,008	1,112	
1845	Unmanured	23¾	1,441	2,712	
	Ammonia-salts	32¾	1,980	4,266	
Average of 19 years, 1845—1863	Unmanured	16¼	1,031	1,723	
	Ammonia-salts	24½	1,575	2,737	
Total in 19 years, 1845—1863	Unmanured	310	19,597	32,740	5
	Ammonia-salts	464½	29,932	52,008	8

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nence of season in favouring or impeding the growth of wheat, ain variation in the amount and quality of produce under con- ; but this was not sufficient to obscure the differences referable

onstituents removed from the land during this period, without have been made in ordinary practice, by the supply of farm- l further evidence of the immense resources of the land in this that already referred to in the case of the unmanured land.

of any increase in the amount of produce obtained in 1844 by l land manure consisting only of ash-constituents of wheat, mount of produce obtained in the following year by using only ith that on the unmanured land in 1845, are together most nough in 1844 the chemical conditions of fertility were collec- growth of a full crop of wheat, still there was no deficiency conditions which appertains exclusively to the soil—viz., the constituents. Those results also prove, on the contrary, that nount of ash-constituents in the unmanured land was far in nical conditions requisite for the growth of wheat—viz., the ied, by the atmosphere and by the soil, during the period of the system of cultivation under which the land had become is crop, had admitted of a large accumulation of surplus ash- l have remained useless in the land without a corresponding g the period of growth. The exhaustion consisted in the -food capable of being supplied from within the soil; and, amount of produce could only be effected by an artificial supply that furnished by the manure of the farm.

lture in many localities does not require that the amount of be very large: the only thing necessary, in many instances, is f fertility, and the natural amount of produce is quite suf- e, as in those countries which are the chief sources of the cases, the manure produced by the internal economy of the ide an adequate supply of air-food from within the soil.

where the population is dense, and land is of high value, agri- ifferent character. Its object then is not merely to maintain ility, but to produce, year by year, in the most profitable area of land, the largest possible quantity of the materials of s; to increase, by artificial means, the amount of produce upon ling as much under natural conditions. (See Liebig—1843—*cations to Agriculture and Physiology*, 3rd edit. p. 112; 1847—*Journal of the Royal Agricultural Society of England*,

f employing artificial manures—of augmenting artificially the rtility. For the practice of agriculture under these circum- et from those of agriculture conducted only with a view to the ation, the problem to be solved by the chemist for the guidance bstances to supply as plant-food from extraneous sources, in year, a remunerative produce.

y one as to manure: its solution, however, involves the con- nd reqirements other than those obtained in natural vegetation, quantitatively different. Still, the knowledge of the general ition must be the guide in the endeavour to solve this problem. hat the various materials of plant-food must bear a certain in order to be in the highest degree effective, and since the wn to be limited by the quantity of that food-material which le amount, relatively to the requirements of any particular crop, rd to the artificial means of increasing the amount of produce, d-material becomes deficient, relatively to others, under the he growth of that crop. The deficiency may lie in the source of the supply of water or of available ash-constituents, or of some er it be, the amount of produce will be limited by the deficiency. hat point will indicate, therefore, what food-material it is most icially, in order to render effective in the highest degree those available in greatest abundance, relatively to the requirements The food-materials least available abundantly in the same at particular case, the manure to be supplied artificially in eased produce. This is the fundamental principle of "high

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farming," which really consists in augmenting the acrea
year, crops larger than could be obtained under natural
effective the existing natural conditions of fertility.

This object may be attained in part by the right sele
to accumulate on the farm the materials of plant-fo
deficient, in regard to the whole of the crops grown
adapting the method of cultivation so as to store up,
materials of plant-food which are relatively most deficie
grown at intervals, and to make that accumulation
amount of produce of that crop.

It is not by substituting for the manure produced b
farm, some one or other of its constituents, that this ol
supplementing it with what is most wanting, either na
of that branch of industry which is the business of the fa

Practically there is a limit to the increase of produce,
which is due to climate and to season; it is the necess
produced and maintained should be remunerative. Th
introduces into the subject an important complication, i
number of circumstances which cannot be entered upo
suggest themselves to the reader.

In order to obtain such an amount of produce in corn
case, it is necessary to supply during the period of growth
air-food than would be furnished during that period by
vided, in addition to that, by the internal economy of th
meadow-grass was grown besides corn.

This might be effected by the use of ammonia-salts a
ammonia is too limited to be alone sufficient in agric
had to the accumulation of ammonia from the atmosp
which possess the capability, under certain conditions,
that source, to a much larger extent than either wheat, b
employed as food for cattle so as to produce meat—a ma
to corn—and, at the same time, a larger supply of m
if the land remained in bare fallow, or were converted a

The manure so produced by the internal economy of the
part of the nitrogen collected from the atmosphere by th
corn-crops, and used in feeding cattle, and would serve
furnish the augmented supply of nitrogenous air-food n
crop of corn.

The plants which are cultivated mainly with this obj
turnip, since it presents a striking contrast to corn-crop
most favourable to increase in the amount of produce, a
bilities and requirements, though it is inferior to legu
assimilating nitrogen from the atmosphere.

The amount of produce obtained under the system of
in this country is considerably higher with regard to all
countries; and though there is a difference in this respec
accompanying table may be taken to represent a fair a
tities of the several constituents of the different crops
termed a "four-course rotation," when a crop of turni
between two crops of corn.

The growth of the turnip as an agricultural crop, so
produce, is far more liable to be influenced by differen
with wheat. In the absence of rain, at a particular
number of the plants may die, and the acreage-produce
conditions of season be favourable, the amount of produ
20 or 30 tons per acre.

It has been supposed that the influence exercised by t
a fallow-crop, in restoring and augmenting the fertility o
increase of the wheat-crop, was referable to its comp
appropriating, by means of its large leaf-surface, the a
during its period of growth, and to its requiring but
materials from the soil. (See Davy, *Op. cit.* viii. 76, 7

That this is not the case, is evident from the amount
in the turnip, as shown in the table just referred to;
apparent by the following results of experiments by L
showing the amount of produce obtained by growing turni
on the same plot of land without manure.

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on of the Acreage Produce of Different Crops.

Corn Crops.			Root Crops.			Leguminous.	
Wheat. 30 bush.	Barley. 40 bush.	Oats. 44 bush.	Turnips. 10 tons.	Swedes. 13 tons.	Mangel. 16 tons.	Beans. 34 bush.	Clover-hay. 5,000 lbs.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1,800	2,080	1,672	22,400	29,120	35,840	2,180	
3,000	2,500	2,500	8,960	2,912	5,376	2,400	
4,800	4,580	4,172	31,360	32,032	41,216	4,580	5,000
1,530	1,716	1,438	1,792	3,203	4,301	1,809	
2,520	2,175	2,075	1,165	379	537	1,968	
4,050	3,891	3,513	2,957	3,582	4,838	3,777	4,150
31	46	47	134	144	359	60	
151	125	137	146	42	91	132	
182	171	184	289	186	450	192	373
32	33	37	36	64	90	86	
19	17	19	41	15	. .	27	
51	50	56	77	79	90	113	124
15	15	10	13	14	18	20	
8	5	6	7	3	5	9	
23	20	16	20	17	23	29	28
9	11	8	60	43	100	24	
20	19	23	29	7	21	28	
29	30	31	89	50	121	52	75
1	1	2	16	16	13	4	
8	11	10	44	12	8	28	
9	12	12	60	28	21	32	112
3	4	3	3	4	9	5	
3	3	5	1	1	7	6	
6	7	8	4	5	16	11	32
1	13	22	1	2	9	1	
101	75	68	2	1	2	5	
102	88	90	3	3	11	6	11

of the cultivation of the turnip being the production of food
ired to reach maturity, as is the case with wheat; and it is
tmost possible development of the fleshy root, so as to afford
ng both nitrogenous and non-nitrogenous substances in fitting
pose. During the early stage of growth, the young leaves of
e attacked by insects, and it is therefore necessary to forward
idly as possible until the plants become sufficiently strong to
fluence. The number of plants per acre is therefore an im-
e efficacy of the manures used.

r the experiments was a rather heavy loam, not of the best
of turnips; and three crops—wheat, clover, and wheat—had

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been grown upon it since it was manured. The var
known as Norfolk white. To ascertain the capability of
food, and the relation which the turnip bore to the soil
a plot was left each year unmanured. On this plot th
small even in the first year, and in the third year the
two ounces each; so that in regard to the growth of
soil are soon exhausted, and some supply of manure
growth of the turnip as a fallow-crop. (See Lawes
viii. 38.)

Effect of various Manures on Growth

	Plot.	Quantities of Manure per acre.	Number of plants per acre.	Average weight of bulb. lbs.	Fr bu lb
1843	2	Unmanured	17,940	0·52	9,
	1	12 tons farmyard manure	15,571	1·36	21.
	7	56 lbs. ammonia-sulphate	14,996	1·03	15
	3	728 lbs. rape-cake	17,043	1·08	18.
	22	504 lbs. superphosphate	18,446	1·47	27.
	8	280 lbs. superphosphate, 420 lbs rape-cake	16,096	1·69	27.
	18	Mixed phosphates, 551 lbs.	19,642	1·35	26,
1844	2	Unmanured	13,736	0·36	4.
	1	12 tons farmyard manure	20,096	1·19	24.
	22	Superphosphate, 560 lbs.	21,205	0 81	17.
	11	Superphosphate, 448lbs., rape-cake, 448 lbs., ammonia, 15 lbs.	10,320	1·29	13.
	18	Mixed phosphates, 448 lbs.	18,624	0·68	12.
1845	2	Unmanured	13,296	0·11	1.
		Top-dressing A. 1,120 lbs. rape-cake	24,944	0·67	16.
		Top-dressing B. 336 lbs. amm.-sulph.	15,456	0 07	1.
		Top-dressing A and B mixed	24,160	0·50	12.
		12 tons farmyard manure	23,731	1·61	38,
		Top-dressing A. 1,120 lbs. rape-cake	. .	. .	.
		Top-dressing B. 336 lbs. amm.-sulph.	23,104	1·45	33,
		Top-dressing A and B mixed	. .	. .	.
	22	Superphosphate, 1,232 lbs.	24,352	1·17	28.
		Top-dressing A. 1,120 lbs. rape-cake	23,544	1·33	31.
		Top-dressing B. 336 lbs. amm.-sulph.	23,424	1·06	24.
		Top-dressing A and B mixed	23,936	1·17	28.
	18	Mixed phosphates	24,448	1·16	28.
		Top-dressing A. 1,120 lbs. rape-cake	23,404	1·33	31.
		Top-dressing B. 336 lbs. amm.-sulph.	24,448	1·18	28.
		Top-dressing A and B mixed	23,392	1·25	29.

With farmyard manure, which may be considered as
of a large crop of turnips, the number of plants in eac
of season during the early stage of the growth; and th
represent the influence of season during the stage of bu

Ammoniacal salts operated in most instances prejudi
growth, especially when placed near the seed; when
carbonaceous manure, the development of bulb was
and the development of leaf was much increased; but
these bulbs was generally less than in others, and
substance was greater—just the opposite of what happ

With a considerable supply of ammonia, the vigo
accompanied by a less rapid advance towards matur
less favourable for providing a supply of root-food tha
further growth. In this respect the influence of artif
the amount of produce of the turnip-root and of whe
and it is evident that in the cultivation of the turnip
fallow-crop for obtaining a supply of manure, it is cap
from the atmospheric supply during its period of gro
such an extent as not to require any considerable supply

The influence of soluble phosphates in promoting the
well indicated in each year by the number of plants, b
other manures; but it is only during that stage of the
increase the amount of produce in bulbs, as will be se
of the bulbs grown with phosphates only supplied as m

In the plots supplied with manure capable of furni
carbonaceous air-food, the development of the bulbs, in

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ble than in any other case, except where soluble phosphate
, and where the exceptional result was probably referable to
in the soil. The influence of a supply of air-food from within
ment of bulb, is still more strikingly illustrated by the con-
l and third year's results. Though with soluble phosphates
e, the number of plants was always considerably greater than
age weight of bulbs was very small; while on the plots where
ether with a carbonaceous manure, the average weight of the
ger bulb-development. That, together with a greater number
ly the largest amount of produce.
resence of carbonaceous substances capable of supplying food-
soil, is rendered more strikingly evident by the results of the
the season was, on the whole, more favourable than that of
though the number of plants was greater, the amount of
s, in consequence of the slower rate of growth and bulb-forma-
also, the deficient bulb-development within the period of
ere phosphates alone were used, as compared with the results
ous manures were also supplied, shows the importance of pro-
t-food in order to insure rapid growth, and to obtain a large

d upon the composition of the bulb by the ratio existing
bonaceous and nitrogenous air-food from within the soil, is
fferences in the amount of nitrogen in the dry substance of
rmyard manure and rape-cake alone, and with addition of
grown without manure and with top-dressings containing
rbon- and nitrogen-yielding materials.
however, are serviceable only in the later stage of growth by
-material for the development of bulk; and in the earlier
even be prejudicial if placed near the seed, as indicated by
nts in the first two years when these manures were drilled with
herefore, be placed so as to be only within reach of the young
loped its accumulative organs under the influence of the
be placed as near as possible to the seed. The advantage
by the greater number of plants in the third year, when these
a top-dressing to the land.
s with the quantity of phosphoric acid contained in the turnip,
influence of phosphates on the growth of this plant cannot
the mere supply of material serving for the production of
ing a constituent of it. Though the amount of phosphoric
not larger than that in the wheat-crop, a direct supply of
s, from very general experience, to be much more influential
ent of the turnip than in the growth of wheat. Hence it is
the conclusion that it exercises some important and essential
r mode of development requisite in the cultivation of the
ding-crop, other than that which is represented by the amount
ned in the plants.
the supply of potash as a constituent of manure was not
ourable influence, either upon the mode of development of
the amount of produce; nor was it to be expected that this
of growing wheat without manure for several consecutive
ficient in supply of potash for the growth of a turnip-crop,
potash required by it is so much larger than that needed for

removed from the land in the turnip-crop does not cause
tituents to any sensible extent; for, excepting a small portion
luced by the use of the turnip in feeding live-stock, they are
in the manure; and if artificial phosphate-manures be em-
of turnips, the abstraction of this constituent from the land
be to a great extent compensated, if not covered.
ibed will serve to show that the cultivation of the turnip is
f the farm, by means of which nitrogen is stored up as part
the land, and, after having served intermediate purposes,
the important result of increasing the amount of produce
ans that concentration of the atmospheric supply of nitro-
ted, so as to furnish the corn-crops, during their period of
ch as they could otherwise obtain directly from that source
ability of appropriation.

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Though the turnip has here been referred to as a p
stances of its cultivation, a strong contrast to corn-crop
leguminous crops—such as clover, beans, and tares—that
from the atmosphere. In the cultivation of the turni
supply of nitrogen over and above that provided by th
requisite; but it draws largely upon the supplies of nit
in this respect it tends to render an artificial suppl
necessary for the succeeding corn-crop (Lawes and
Journ. Chem. Soc. [2] i. 100). Leguminous crops, on
land richer in nitrogenous supply, and thus to augment
crops of corn. The influence of clover in this respect
Kirwan, *Op. cit.*, p. 166.)

In the cultivation of land under such circumstances
duce sold during 4 years to be 30 bushels wheat, 35 bus
produced from 10 tons turnips and 5,000 lbs. clover-h
imported food, the quantity of ash-constituents removed
utmost, as shown in the following table:—

*Quantities of Ash-constituents per Acre abstracted fro
Farm during Four Year*

	1st Year.	2nd Year.	3rd Year.	
	Live-Weight from Turnips.	Barley.	Live-weight fro Clover-hay	or Bea
Amount of produce.	10 tons.	35 bushels.	5,000 lbs.	1,500 l
Fresh produce .	22,400	1,820	5,000	1,500
Dry produce .	2,464	1,529	4,200	1,260
Nitrogen . .	. .	30	. .	. .
Total ash .	2.46	40·5	3·13	1
Phosphoric acid	0·98	13·4	1·05	0
Potash . .	. .	9·75	0·16	0
Silica . .	. .	11·4	. .	. .

It now only remains to consider the means of mai
aceous material requisite as one of the conditions of the
produce in turnips. In the feeding of animals there i
ration, amounting to nearly one-half of that containe
necessary to increase as far as possible the quantity of n
economy of the farm, by the use of imported food-materi
once a profitable mode of converting those materials in
and of obtaining a larger quantity of manure for the c
taining, or even increasing, the fertility of the land, b
constituents—which compensate for the export of corn—
gen and carbon in a form capable of becoming available
supplies of air-food, auxiliary to those furnished by th
yard manure resulting from the crops grown.

On a farm cultivated under such a system, the exhau
precluded; and although the existing system of dispo
total loss of the phosphates and potash contained in the
that, as regards the extent of land at present under culti
available sources of those substances in the mineral king
loss for a long time to come. Still, the disposition of to
to be available in fertilising land, and to be useful rath
annoyance, is a requirement which is every day more ur

Having thus considered the nature of the difference
between spontaneous vegetation altogether unaided by
assisted by tillage—on the other, between agriculture
obtaining the natural amount of produce, and agriculture
by artificial means, it is now necessary to consider wha
of the general knowledge of the chemistry of vegetatio
been entertained with regard to it.

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to agriculture the theory of plant-nutrition which he con-
als furnished by Saussure, Davy, Sprengel, and Bous-
fundamental proposition, that plant-food consists solely of
monia, and the ash-constituents. In endeavouring to ascertain
y of manure; the mode in which it acts; the circumstances
thods of culture depend; and to establish rules for a rational
he addressed himself first to the questions, "What does the
the materials called manure contain?" as questions whose
l the starting-point of rational agriculture (*Chemistry*, &c., 1st
quiry his attention was mainly directed to the ash-constituents
parison of these with the constituents of soils and of manure
ated plants contained potash, phosphoric acid, and other ash
resence of these substances was constant in particular plants,
at every productive soil contained the same substances; that
rowth of a particular crop on the same land rendered it less
t crop until an interval of some years had been allowed to
t,—he came to the conclusion, that the capability of land to
o the presence in it of the ash-constituents of plants; that the
d nitrogen was dependent upon the presence of the ash-con-
limited by the available amount of them: consequently, that
as proportionate to the available amount of ash-constituents
edit. pp. 113–123). From the same data he concluded that
observed when a particular crop is raised year after year on
o the abstraction of ash-constituents from the soil. (*Op. cit.*

at animal excreta and the plant-remains in farmyard manure
onstituents as the plants which had been consumed as food;
ed a fertilising influence upon land naturally unproductive, or
tion of crops,—he concluded that the efficacy of this manure,
as the ashes of the food burnt in the bodies of animals, was
nts it contained; that its peculiar action consisted in and was
restoration of the ash-constituents, which the land was either
deprived of by previous crops. (*Op. cit.* pp. 176–187; *Address*
Great Britain, pp. 7–12.)
facts that the produce of land could be increased by manure,
he crop is directly proportionate to the quantity of manure
this effect was referable to the amount of ash-constituents
at if the supply of those constituents were greater than the
he previous crop, the amount of produce would be increased;
m were less than that, the produce would be reduced; and
to the quantity removed, the produce would remain constant.

ions as axioms to be observed in practical agriculture, Liebig
oduction of the organic constituents of plants from carbonic
a was determined by the presence of the ash-constituents pro-
ed (*Chemistry*, &c., pp. 196, 204); that its extent was limited
of them in the soil (*Op. cit.* p. 203); that the efficacy of
e amount of produce, by furnishing a supply of carbonic acid
led by the atmosphere, was subject to the same limitation
he amount of produce was so entirely independent of the arti-
that if only the ashes of solid and liquid excreta were supplied
ivated would derive their carbon and nitrogen from the atmo-
203–204); that the ammonia of the atmosphere, exceeding the
nts, was fully sufficient for all the objects of agriculture, even
one, the production of nitrogenous constituents of plants to
d animals. (*Op. cit.* pp. 54, 211.)
se substances was represented by Liebig as depending upon
of phosphates, which enabled plants to derive the requisite
phere—a source where the abstraction of that element was
ed by the ammonia resulting from the decay of animals and
other sources (*Op. cit.* pp. 147, 212). He also insisted that it
ortance for agriculture, to know with certainty that the arti-
a was unnecessary and superfluous for the growth of most
at the value of manure could not be estimated, according to
rance and Germany, by the amount of nitrogenous substances
. 213.)
ominence to his opinion as to the superfluity of nitrogenous

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manure, Liebig instanced the large quantity of nitrogenous substa
hay, milk, and flesh—on grass-land without any supply of nitroge
contrasted that fact with the smaller produce of nitrogenous cons
within the same period—as corn and roots—on land to which nitro
plied as manure in greater quantity than was contained in the p
referred to the export from Egypt of ammonia, obtained by burning a
the proverbial fertility of that country, where only the ashes of exc
mud, containing little nitrogen, had been used as manure for ages
cheese from Holland and Switzerland,—as rendering it perfectly cer
dution of nitrogenous constituents of plants was not proportionate
nitrogen supplied to the land in the manure: that the export of ni
was not exhaustive; because it was not the soil, but the atmosphe
nitrogen to plants: that it was impossible to augment the produ
supply of highly nitrogenous manure, or of ammonia-salts alone;
contrary, the capability of land to produce crops increased or diminis
portion to the ash-constituents supplied to it in the manure. (*Op.* c

The logical consequence of the opinions thus formed, was to re
stituents as the essentially, if not the only, effective portion of manu
It was insisted upon as a point of especial importance for the pract
deceive himself concerning the cause of the efficacy of manures (*Op.*
this respect the ash-constituents were compared by Liebig to the qu
bark, the iodine of burnt sponge, or the active principles of opium
Consequently, the ash-constituents of manure were the materials w
his view, it was essential for the farmer to supply to land artificially, i
the amount of produce. (*Op. cit.* p. 203, 211.)

The fundamental principle of rational culture, according to that vie
restoration of the ash-constituents removed from the land; and wheth
were made by applying excreta, or ashes, or bones, was regarde
indifference (*Op. cit.* p. 187). The particular kind of ash-constitue
manure, was to depend upon the kind of produce required; alkalis
of substances analagous to starch: phosphates for the production of
stances (*Op. cit.* pp. 193, 142, 144, 148). By the exact determinati
of ash in cultivated plants, and by the analysis of the ashes, the q
substances removed from land by crops was to be ascertained. Thu
to be enabled to keep a debtor and creditor account, for each of his fi
ash-constituents removed from the land, year by year; and to deter
the kind and quantity of the crops raised upon it, what substances an
of them were to be returned to the land, in order to restore its ori
fertility, or to be able to express exactly how many pounds of one or
was to be supplied to the land in order to augment the amount of pr
pp. 213, 214.)

Extending this view of the chemistry of plant-nutrition to the explana
operations of the farm, the practices of rotation, fallow, &c, Liebig,
his attention upon that particular aspect of the chemistry of agriculture
constituents of plants, soils, and manure are concerned, ascribed the inf
rendering land again capable of supporting the growth of corn, solely t
the ash-constituents requisite for that crop, by the decomposition of alka
land during the interval of fallow (*Op. cit.* pp. 118, 130–133). The
of burnt lime and burnt clay on some soils, was ascribed to the sam
He represented the advantages of rotation of crops as being, to so
the production of humus in the soil, but chiefly to the unequal
the different alternating crops for particular ash-constituents, and t
accumulation, during the greater part of the period of rotation, of thos
present in least available amount in the soil, and requisite for the gr
in larger amount than for the growth of the intervening crops. (*Op.*
169, 172; Berzelius—1844—*Jahresbericht*, xxiv. 333.)

This theory of the chemistry of agriculture was applied by Liebig
of artificial manure; and a patent was obtained by Muspratt for the
facture, as a communication from Liebig (*Improvements in the Manuf*
1845, Specification No. 10,616). These artificial manures were inte
the land exactly what was wanting for the growth of any particular
effect an economy which would be impossible while manure was a
nately—the useful and the unnecessary constituents together. But the
which these artificial manures were to secure, were to render the rota
fallowing unnecessary and superfluous, and to admit of one and
crop being grown, year after year, upon the same field—of a pere
without the necessity either of fallow or of a rotation of crops, which

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excluding all that science might be able to teach (*Principles*, es, which were intended to effect such an entire revolution in onsisted chiefly of compounds of potassium-carbonate, with cal- osphate, potassium-silicate, gypsum, bone-earth, and salt, and monio-magnesian phosphate, equivalent to rather less than 0·25 he manures. The following table contains analyses of these red by Messrs. Pfeiffer, Schwarzenberg, & Co. in Cassel (Pabst *haftliche Erfahrungen von Hohenheim*, p. 13). For the sake of ated composition of the manures, according to the directions of ded:—

Composition of Liebig's Artificial Manures.

For Cereals.		For Leguminous Crops.		For Root-Crops.		For Tuber-Crops.
	Calculated		Calculated.		Calculated.	
. .	0·28	. .	0·24	. .	0·40	
9·30	40·32	11·38	26·28	14·60	19·10	15·31
10·00	4·72	13·70	13·20	4·02	15·73	3·33
21·20	9·16	25·23	16·20	32·20	20·05	26.15
3·75	0·64	1·67	0·64	1·55	1·06	2·92
5·05	. .	1·48	. .	1·36	. .	6·35
5·50	6·00	1·50	9·76	2·37	14·20	0·22
10·08	3·72	9·17	3·72	6·70	3·06	9·67
1·04	. .	1·16	2·40	1·68	. .	1·14
9 82	7·56	14·33	16·48	25·20	21·60	19·47
24·30	. .	18·39	. .	9·08	. .	18·40
. .	26·00	. .	8·32			
. .	3·00	. .	2·96	. .	4·50	
00·04	100·00	98·01	100·00	98·76	100·00	99·12

on of manures for other plants, was to be ascertained by burning ng the ashes, and then combining the manure according to the 4, line 27). In the *Address to Agriculturists*, explaining the nanuring, Liebig stated his view that "the exhaustion of the s—its decrease in fertility—is produced by the gradual removal s, in a soluble state, which are necessary for the development of By a supply of manure they are again restored to the state rishment to a new vegetation. If the supply of the removed y means of manure, be sufficient, if the quantity taken away be rtility reappears; if the supply be greater, the produce increases; s a smaller produce" (p. 12); or, in other words, the amount of roportionate to the available quantity of ash-constituents, or ich, "as such, are indestructible by fire, and consequently remain eration of the plants, or of their parts." (p. 8.)

griculturist was to confine himself to supplying these substances it the proper physical condition, so as to render possible, and to on of carbonic acid and ammonia from the atmosphere.

iculture, or of manures—known as the mineral theory—was sm in England and America, and the estimation in which it was d by the following comments, published shortly after the intro- ures:—"Since the organic food-materials are universally supplied mount, the great difference of vegetation cannot be sought in y, must be due to the inorganic constituents; so that, in putting d, it would be essentially quite the same if it were first burnt, ewed upon the land, since its efficacy can only be due to its ash- y to perceive that this principle, applied to agriculture, suddenly all phenomena whose explanation has hitherto been sought for asy to conceive why irrigated meadow-land can yield annually ay without manure when the necessary quantities of salts are water. It becomes clear how the Peruvian is able to obtain ize upon the most arid sand-drifts, if only a tiny rill from the les conveys to them the requisite soluble earths. Hundreds of e elucidated by this ingenious idea of Liebig's; but hundreds suggested fruitful in development and improvement for that

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simplification and security of agriculture which will be th
we begin to find it natural that in England—where, acc
known, agriculture stands so high—Liebig should be
rational system, in opposition to the previous purely emp
be overwhelmed with laudatory demonstrations and m
as scarcely any one, and certainly no foreigner, has
Schleiden, *The Plant*, pp. 173-174.

Under the auspices of the Royal Agricultural Society
vestigation of plant-ashes was undertaken by Way a
obtaining data for the preparation of artificial manures
theory of agriculture (*Journ. Roy. Agric. Soc.*).

But experience did not realise the expectations which
results to be obtained by the use of manure prepared
the "mineral theory." Among other places, the wheat-m
and the following results were obtained. (See Lawes a

Plot.		Dressed corn per acre.
	1843–44	bushels.
3	Unmanured	15
2	Farmyard manure, 14 tons . . .	20½
4	Ashes of ditto „ . . .	14½
10	Superphosphate, 560 lbs.; potash-silicate, 220 lbs.	15½
17	Mixed phosphates, amm.-sulph., 65 lbs. .	19
19	„ „ „ „ 81 lbs. .	24⅛
	1844–45	
3	Unmanured	23
2	Farm-yard manure, 14 tons . . .	32
6	Superphosphate, 112 lbs.; ammonia-sulph., 112 lbs.; rape-cake, 560 lbs. . . .	28¾
10	Amm.-sulph. and chloride, 336 lbs. . .	32
	1845–46	
3	Unmanured	18
2	Farmyard manure, 14 tons . . .	27
6	Liebig's manure, 448 lbs.. . . .	20¼
	„ „ „ amm.-salts, 224 lbs.	29½
7	„ „ „ rape-cake, 448 „	22¾
	„ „ „ amm.-salts, 224 „ & rape-cake, 448 „	31⅜
10	Ammonia-sulphate, 224 lbs. . . .	27½
	Unmanured	17⅜

Comparing the amount of produce obtained by the
that obtained where only the ash of an equal quantity o
it is evident that the use of this manure effects somethin
tion of ash-constituents to the land: and this result
error of the "mineral theory of agriculture."

It has already been shown that the land, though exha
of wheat under the ordinary system of cultivation, w
constituents (see *ante*, p. 837): consequently, the applic
was not attended with any increase of produce over that
which may be regarded as the measure of the extent to
air-food by the atmosphere and soil was available fo
wherever ammonia was supplied as manure, the produc
even in those exceptional instances where it was used al
in direct opposition to Liebig's mineral theory of agric

In the case of wheat, the capability of production do
exact proportion to the ash-constituents supplied to lar
of produce is proportionate to the supply of nitrogen in
production may be increased by manure rich in nitroge
alone. (See Chatterley—1843—*Phil. Mag.* xxii. 470
with saline manures, containing nitrogen.)

It is, therefore, the relative deficiency of the supply o
be regarded as constituting the principal feature of that
to the growth of wheat, which takes place in the ordinary

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o those above described have been made on the light land of d the same general results have been arrived at. (See Lawes xvi. 207. xxiii. 31.)

rnish a clue to the function of farmyard manure in the growth e the mere restitution of ash-constituents, and they illustrate ccumulation of available nitrogen upon the farm by the cultiva- Moreover, they are conclusive proof that, so far as relates to wheat, the value of this manure is more essentially dependent ogenous material which it provides, than upon the restoration oved by former crops; though this latter is a necessary condition rtility in regard to long periods of time, and one which always stem of farming.

presented by wheat and turnips in regard to amount of produce, year on the same land without manure, clearly indicates that, turnip, by which the exhaustion of land, by previous crops, is ary practice, a supply of air-food from within the soil requires to Though the produce of wheat—allowing for the influence of onstant during twenty consecutive years, the produce of turnips ears to almost nothing. Consequently, the capability of this food-materials furnished by the atmosphere during its period of as has been supposed, and is, indeed, inferior to that of wheat. f manure in regard to these crops respectively, is also shown by h phosphates, with ammonia-salts, and with farmyard manure. d to wheat afforded no increase in the amount of produce out manure; but with turnips it always increased the amount of n there was an abundant supply of carbonaceous air-food pro- at furnished by the atmosphere within the period of growth. to turnips, either with or without other ingredients of manure, pplies of ash-constituents in the land, did not increase the favourable mode of growth; but with wheat, under the same oubled the amount of produce. Farmyard manure—containing monia, or its equivalent, together with a large amount of carbon- d to wheat did not increase the amount of produce more than obtained without manure; but with turnips its use was crease in the average weight of the bulbs; and when soluble sed, there was a very considerable increase in the amount of difference in these cases is chiefly referable to difference in the plants as they are cultivated; a comparatively more abundant food and of phosphates being necessary for the turnip, while ratively more abundant supply of nitrogenous food.

uce obtained with Liebig's wheat-manure, in the third year, tained without any manure, and much less than that obtained ; but when ammonia-salts were used with Liebig's manure, e was increased nearly in proportion to the amount of nitro- d either as ammonia-salts or rape-cake.

efore 1845 by Liebig himself, with these manures consisting s, did not furnish any indications of their efficacy; and in subse- uncultivated land at Giessen, the effect produced where they y slight, compared with that where forest-earth or stable-manure *rinciples*, pp. 40–45). By cultivation, the fertility of the land ut as no data have been given as to the composition of the soil, &c., by which an opinion could be formed as to what were the land—how much of the result may be due to the influence of re produced as the result of cultivation only, and how little of to the supply of ash-constituents to the land in the first year— d the results of these experiments as constituting any exception le elsewhere as to the effect of manure consisting wholly of ash-

ig's wheat-manure, and the inefficacy of the ash of farm-yard ibed to their deficient solubility. (See Liebig, *Einleitung in dbaues*, pp. 70 *et seq.*; International Exhibition, 1862, *Reports by* his opinion may be urged as an excuse in those instances, but it the other instances in which the constituents of the wheat- es were used in a very soluble condition, and were nevertheless ugmenting the produce beyond that obtained without manure. n could not, therefore, consist in deficiency of ash-constituents; d by the use of ammonia, even alone, or with those manures,

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clearly prove that the relative deficiency of nitrogeno
growth, was the main feature of the exhaustion, the d
amount of produce on the unmanured land, and of the i
stituents, if not also of the farmyard manure ash and of

These results, therefore, show that all hope of obtain
increasing the amount of produce of crops generally, by m
of the ash-constituents of the plants grown, must be en
regards agricultural practice, precisely the opposite cours
air-food by artificial means, in order to render the avail
effective. The artificial supply of nitrogenous air-food
full agricultural crop of corn can be obtained year after
since the sources of ammonia-salts at present availabl
pose, it is evident that a rotation of crops is an indispe
agriculture where the production of corn is the chief ob
to obtain a large amount of produce. The increased sup
atmospheric sources by the cultivation of fallow-crops,
feeding for the production of corn, must at the same
purchase, from extraneous sources, of nitrogenous manure
be practicable and profitable in particular instances. I
constituents, the artificial supply of nitrogenous manure
tuted for rotation, and cattle-feeding, so as to obtain large

It appears, therefore, that instead of reforming agricu
caused them to demonstrate the incorrectness of his
and the failure of those manures, from the applicatio
induced to anticipate such wonderful results, naturally p
which was sometimes expressed in a manner not alt
opposition to the views put forward by Liebig. Th
Agricultural Society of England, after remarking, in
mineral theory, hastily adopted by Liebig, had broken
the increase or diminution of crops being exactly propor
nution in the quantity of ash-constituents supplied to th
death-blow from the experiments at Rothamsted," went
principles of manure, ammonia was specially suited for
(Pusey—1850—*Jour. Roy. Agric. Soc.* xxii. 383-392.)

This expression of opinion by a practical farmer m
chiefly to the artificial supplies of manure required for
not by any means indicative of the idea that, in regard
sidered apart from agriculture, any one or other constitu
special value independent of others. The erroneous est
the opinions held in this country respecting manure, has
position that such an idea has been entertained, or else th
of the farmer's strictly technical view of this subject bei
of materials to be provided over and above those sup
ordinary practice, either from extraneous sources or by

That erroneous estimate has also given rise to much
which Liebig has manifested towards the conclusions a
Lawes and Gilbert, though virtually adopting thos
modifying his own views in accordance with them. It h
the general doctrine of plant-nutrition has been called in
case; nor has this general doctrine ever been disputed, ex
extreme form of it, adopted by Liebig, according to w
ammonia are held to be the only sources of the o
(Saussure—1841—"Sur la Nutrition des Végétaux.
Berzelius—1842—*Jahresbericht*, xxii. 220.—Mulder,
The originality of that extreme view was, indeed, dispute
also put forward about the same time. (Dumas—1841
atmosphérique dans la nature, et sur l'action qu'il exerc
Rev. scient. indust. vi. 228, and *Chemical and Physiologic*
Berzelius, in criticising that doctrine, remarked that,
by any experimental evidence, it was so opposed to ge
that it could not even be regarded as probable; though it
spiration, and had been propounded with the art peculiar
by soundness of argument, to overcome the doubts of thos
than to impress others, less cognisant of it, by striking m
the most efficient means of making precipitate scientific
(*Jahresbericht*, xxii. 220). In reference to Liebig's vie
ture, he also remarked that the mode in which he had so
highest importance for that art, had met with greater

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s consistent with the state of knowledge at that time. Of
e contrary, who had followed "the difficult and laborious course
tion by experiment," he remarked, that "his answers, though
stly trustworthy." (*Jahresbericht*, xxi. 236, 238.)
arly recognised by Berzelius between Liebig's mineral theory
oussingault's views on the same subject, has been fully con-
f experience. The former may be looked upon as a thing of the
n has been demonstrated by the entire failure of the attempts to
fundamental principle as to fertility and manure. The latter,
ne particulars by their development, and by the progress of re-
l in the main correct, and are supported by the extended results
nd Gilbert, in the series of experiments they have conducted
, during the last twenty years, with a strict regard to actual
nd in the laboratory, with all the refinement of modern methods

een Liebig's doctrine and the conclusions arrived at by Lawes
esult of their experimental researches, does not relate to the
nt-nutrition; but it relates solely to the ordinary system of
nd chiefly to that branch of the "mineral theory" of agriculture
which comprises the principles of manuring. Liebig ascribed
y of manure, solely to the amount of available ash-constituents
antages of rotation, mainly to the unequal requirements of
se substances.
on the contrary, have shown that fertility is not proportionate to
e ash-constituents in land; that the efficacy of manure is not
mount of ash-constituents it contains; that the exhaustion of
ractice of agriculture, consists chiefly in a deficiency of nitro-
that the advantage of rotation consists more in the accumulation
rbonaceous food-materials in the farmyard manure, than in the
ash-constituents taken from land by corn and fallow-crops; and
of cultivated plants cannot be measured merely by the results of

f the results thus obtained is not overrated by the opinion ex-
address of the President of the Royal Agricultural Society of
g the last twenty-five years, there has not been any addition
, which approaches, in importance, to the insight into the true
ng and manuring, obtained on the experimental farm at
mpson—1864—*Journ. Roy. Agric. Soc.* xxv. 4.)
usions and general views which have been arrived at by these
vehemently disputed by Liebig, who has sought to maintain
totally erroneous, and perfectly confirmatory of his "mineral
(Liebig—1851—*Letters on Chemistry*, 3rd edit.; 1855—*Prin-
istry*; 1863—*Natural Laws of Husbandry, Einleitung*, &c.—
160.)
sition has been arrived at by a singular process.
the "mineral theory" of agriculture comprised ammonia and its
al substances which were considered to determine the fertility of
f manure, and which it was, consequently, necessary to return or
r to maintain or increase fertility. (Liebig—1855—*Principles*
90.)
, is quite inconsistent with Liebig's original exposition of his
inted antithesis constantly maintained in all his writings, between
of plants, carbonic acid, water, and ammonia, whether furnished
phere, or indirectly from within the soil; and those materials
om the soil, which "are mineral substances, and as such are
and, consequently, remain as ashes after the incineration of the
es." It is also inconsistent with the general interpretation of
by other writers on the subject. (See Horsford—1846—*Genesee
Weissenborn—1847—*Farmer's Magazine*.—Schultze—1848,
Report, 1849.—Johnston—1848—*Jour. Roy. Agric. Soc. Eng.*,
4—*Traité des Amendments*, pp. 423, 623, 624, 627, 632.—Bous-
nomie Rurale, ii. 81.—*North British Agriculturist*, Nov. 7, 1855.)
that, in the specification of the patent which was the embodi-
eral theory" in relation to practical agriculture, neither ammonia
ded* among the mineral substances mentioned in the recipes and

onia, amounting to less than 0·5 per cent., corresponding to the ammonio-
e manure, is of course considered as unimportant.

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directions given by him for the preparation of manures (se
also, though ammonia was stated to have been added to th
the prospect of being able to exclude it altogether was s
the third edition of the *Letters on Chemistry*, 1851, (p. 502
to the argument, that an artificial supply of nitrogen was
(p. 515); for though such a supply would exercise a favour
if it were not given, all the requisite nitrogen would be c
(p. 518. See also *Allgemeine Zeitung*—1857—No. 157.)

In the criticism of Lawes' and Gilbert's experime
has assumed that they have regarded certain substances
materials of plant-food in an abstract point of view; but
Their experiments have only led them to consider tha
and in relation to the existing practice of agriculture, in
materials of plant-food acquire a preponderating value as
in the case of corn, become relatively deficient; or which
particular mode of growth, like phosphoric acid in the cas
the materials to be supplied artificially, not with the ob
resources of land, but in order to prevent these from lyin

Herein lies a difference which Liebig has either fail
disregarded; and it is a difference of the highest impo
accepts, in its full significance, the abstract theory of
concerns him: he also looks for its application to the ar
for rules by which his practice may be improved. Ther
suggestions for improvement have been more eagerly acc
or thirty years than in agriculture; but when such sug
wanting, the practical nature of agriculture demands thei

So it has proved with Liebig's application of his the
culture. Looking only to the ash-constituents of plants
has laid down rules for agricultural practice—he has pre
elaborate expositions of the various operations of culture,
failed to bear the test of experience.

But where the enquiry into this subject has been condu
and by a method at once more philosophical and more d
conditions of practical agriculture, as in the experiment
Lawes and Gilbert, the results obtained are calculated t
mate induction, by which principles of real value in rela
may be arrived at.

The customary routine of agricultural practice, howeve
ticular cases, has become established by observation and e
of the same mental functions which are employed in scien
exercise may be limited by the practical object in view
in reality, agricultural customs represent natural facts to
is yet competent to explain. To those who do not, like I
be "destitute of all understanding," the prejudices char
practice will, therefore, appear as the exponents of those
and other circumstances, which lie at the root of the pract
and unintelligible such prejudices and empirical rules ma
sideration of them, that a clue may be obtained to th
improvement of agriculture. The science which is to be
whose value will be recognised by farmers, must grow o
and the patient examination of its various details, and
grafting upon it. The accumulated data of ordinary expe
for its construction, and its doctrines must rest upon evid
probability. It may be a slow growth, but it must be a

Meanwhile, it is no reproach to the farmer if he adhe
knows by experience to have brought him certain result
another system until he has sufficient proof of its being r
with which he is familiar. This natural conservative ten
by the failures attending the premature application of
really the reason why farmers are in many cases averse
ments suggested by science. It is not because they are "de
or because they pretend to deny the existence of any c
doctrines and the phenomena concerned in agriculture, bu
able whether those doctrines really furnish the means
reason they prefer to be guided by tradition and experienc
cepts of scientific speculation. If there be an established
tween the practice of rotation with cattle-feeding, and the

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perphosphates and the production of a large root-crop—between
is manure and the increase of corn-crops—those practices will
d, and they will constitute the scientific practice of agriculture,
the questions whether superphosphate or ammonia have any
rials of plant-food, or what becomes of those portions of them
manure and are not obtained in the crop. These are abstract
high interest for the chemist, and of possible importance to the
but they do not concern the farmer, whose business is to produce
as are at his disposal. It would be a very illogical conclusion
d as to the influence of artificial supplies of ammonia and super-
growth of corn- and root-crops should be disregarded because
explain the precise functions of those substances in vegetation;
ional to denounce, as a folly and an error, the application of those
knowledge will admit. B. H. P.

E. Syn. with BLENDE. (See ZINC, SULPHIDE OF.)

LIMESTONE (p. 697).—Church (Chem. Soc. J. xvii. 379) has
colouring matter of the Blue Forest Marble, and has shown that
of the dark bands which occupy the central portion of the various-
the stone has naturally divided, consists of iron pyrites, while
n, or buff tint of the outer parts of the slabs is due to ferric oxide
dation of the pyrites. It appears probable that the colouring of
clays, rocks, and soils may also be due to the presence of iron
rhaps, may be explained the injurious influence which these blue
t on vegetation.

White iron pyrites. (See IRON, SULPHIDES OF, p. 402.)

name applied to an impure variety of braunite (manganic oxide);
n of rhodonite (silicate of manganese).

A mineral having the aspect of tenorite cupric oxide), from the
River, in the neighbourhood of Mount Witchita. Hardness = 3.
to 4·1. In the flame of a candle it melts, and acquires a blue or
rcoal it gives off vapours of chloride of copper, and ultimately
In the pulverised state, it dissolves completely in ammonia.
nt. copper, 36·2 chlorine and oxygen, and 9·5 water. (C. U.
[2] xxi. 206.)

Syn. with PEARLSTONE.

ID. $C^{17}H^{34}O^2 = \left.\begin{matrix} C^{17}H^{33}O \\ H \end{matrix}\right\}O$. (Heintz, Pogg. Ann. cii. 272.)—
ly applied to an acid intermediate between stearic and palmitic
produced, together with others, by the saponification of solid
s now restricted, for reasons presently to be mentioned, to an
tty acid of the series $C^nH^{2n}O^2$, resulting from a definite reaction.
ic acid.—This acid is produced by the action of potash on cyanide
e):

$$C^{17}H^{33}N + 2H^2O = C^{17}H^{34}O^2 + NH^3.$$

, see i. 841) is continuously boiled with alcoholic potash, till am-
ren off, and the residue has become solid; this residue is then
dilute hydrochloric acid; the separated fatty acid is shaken up
; and the turbid solution is precipitated by chloride of barium.
being washed with water and with alcohol, and repeatedly boiled
his solvent an oil, which solidifies in the cold, melts below 40°,
on of a mixture of cetylic ether and cetylic aldehyde. The un-
is decomposed by agitation with hydrochloric acid and ether; and
ereal liquid, and distilling off the ether, crude yellowish margaric
ing at 56·6°, and solidifying in scales and fine needles. This
, by several crystallisations from alcohol, repeated partial pre-
olution of its sodium-salt by acetate of magnesium, and subse-
of the portions of acid again separated (somewhat in the manner
) into margaric acid, and an acid containing a larger proportion
ormed from cyanide of *stethyl*, $C^{19}H^{37}N$, contained in the cyanide
hich occurs chiefly in the portions first precipitated by acetate of
z.)

recipitated by acetate of magnesium yield margaric acid, which,
has been raised by repeated crystallisation to 59·9°, exhibits the
re fatty acid mentioned below, and cannot in any way be resolved
melting-point. This is the only way in which pure margaric

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acid can be obtained. The acids formerly so called, c
natural fats, were mixtures of stearic acid with palmit
melting-point.

Margaric acid forms white crystals, melting at 59·9
scales on cooling It contains, according to the mean of
per cent. carbon, and 12·51 to 12·57 hydrogen; the fo
12·59 hydrogen, and 11·85 oxygen.

But few of the margarates have been prepared.
obtained by precipitating the sodium-salt with nitrat
water, is a white amorphous powder yielding, by anal
and 22·40 BaO; the formula requiring 60·44 C, 9·78 H

The *silver-salt*, $C^{17}H^{33}AgO^2$, obtained in like manner
loose, white amorphous powder, containing 53·67 per
(calc. 54·11 C, 8·75 H, 28·65 Ag, and 8·74 O).

The *sodium-salt* is prepared by adding a boiling aqu
bonate to a boiling alcoholic solution of margaric acid,
water-bath, exhausting the residue with boiling alcohol
which solidifies to a jelly on cooling, is liquefied by hea
proportion of one-eighth of the volume of the alcohol
liquid is formed which takes up any foreign salts pres
salt is collected on linen and strongly pressed.

B. The *so-called* margaric acid *obtained by sap*
Chevreul in 1820 distinguished the solid acids result
fats, as margaric acid and margarous, afterward
melting at 60°, the latter at 75°, and solidifying at 70°
ference between the two acids to be fully established, t
might be a mixture of stearic acid with another acid m

The fatty acid melting at 60° was, however, afterward
(see Gerhardt, *Traité*, ii. 835), and regarded as a separ
$C^{17}H^{34}O^2$; and this view of its nature continued to preva
searches published in 1852 and subsequent years, sho
acid, but could be separated, by certain processes, into s
of lower melting-point. The leading points established
searches (for the references to which see *Gmelin's H*
following:

1. All the acids obtained in the saponification of fa
carbon-atoms (C = 12).

2. The margaric acid of most chemists is separable in

3. Fatty acids may be mixtures, and not definite c
their composition nor their melting-point can be altered

4. Such mixtures may, however, be separated by par

5. They differ from pure acids as regards their m
solidifying.

Heintz has, moreover, determined with accuracy the
many other properties of the fatty acids, and has also
given, of mixtures of fatty acids of known compositio
(Stearic acids). From these, and the investigations
published, it appears that the nature of the bodies
probably as follows:

a. Margaric acid of Chevreul.—This, according to
mixture of about 90 per cent. palmitic acid and 10
probable from the circumstance that it crystallises in n
nature are doubtless the margaric acid of Varrent
84), obtained from human fat; that from goose-fat by
shea-butter by Thomson and Wood (J. pr. Chem. xl

b. Margaric acid of Bromeis.—The acid obtained
undecomposed stearic acid, which owes its lower me
volatile acids (see Stearic acid).—Respecting the n
(Ann. Ch. Pharm. xxxv. 93) obtained from impure ole
acid, see Oleic acid.

c. Margaric acid of Redtenbacher and Varrentrap
obtained by the dry distillation of stearic acid, when, a
stearic acid passes over unchanged. That of Varrent
65), obtained by the dry distillation of beef-suet, hog
acid, doubtless varies in composition according to the k

d. Anderson's *Margaric acid* (Ann. Ch. Pharm. lx
with sulphydric acid, odmyl, and other products, by th

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ns, on the average, 75·34 per cent. C, 12·58 H; in the silver-
ver; in the ethylic ether, 76·33 per cent. C, 12·73 H, and
be palmitic acid formed by the decomposition of oleic acid.
oleck, Lewy, and others, obtained by the dry distillation or
doubtless palmitic acid, more or less pure.

IERS. No compounds of the alcohol-radicles with pure
s), have yet been obtained. The compounds to which the
applied were probably mixtures of stearic and palmitic ethers.
to Chevreul's *margarin*.

erlglimmer, *Emeryllite*, *Corundellite*, and *Clingmannite*.— A
luminium, occurring in trimetric hemihedral crystals, with a
uscovite; tabular from predominance of the form oP. Angle
120°. Lateral planes longitudinally striated. Cleavage basal,
ersecting or aggregated laminæ, sometimes compact, massive,
ructure. Hardness = 3·5 to 4·5. Specific gravity = 3·032
nargarite (Hermann), 2·995 for emeryllite (Silliman, jun.).
erally vitreous. Colour greyish, reddish, or yellowish. Trans-
Laminæ rather brittle.

erzing, in the Tyrol (Smith and Brush, Sill. Am. J. ii. xv.
ndum mines of Gumuchdagh, in Asia Minor. *c* From the
Grecian Archipelago. *d*. From Naxos. *e*. From Katha-
L. Smith, *ibid.* xi. 59 and xv. 208). *f*. From Village Green,
ania (Craw, *ibid.* viii. 379). *g*. From Buncombe county,
man, *ibid.* viii. 1). *h*. From Unionville, Pennsylvania (Craw,

a.	*b.*	*c.*	*d.*	*e.*	*f.*	*g.*	*h.*
28·55	30·83	30·04	29·68	28·50	31·20	29·17	29·99
50·24	49·30	49·08	49·38	51·02	50·86	48·40	50·57
1·65	2·03	1·48	1·26	1·78			
11·88	10·83	11·20	11·18	12·05	10·25	9·87	11·31
0·69	0·50	trace	. .	. .	0·45	1·24	0·62
1·87	1·90	2·58	1·25	?	2·29	6·15	2·47
4·88	3·88	4·72	5·05	5·04	4·83	3·99	5·14
. .	. .	. .	. .	. .	. .	2·00	
99·76	99·27	99·10	97·80	98·39	99·88	100·82	100·10

the formula $CaO.2Al^2O^3.2SiO^2.H^2O$ (the calcium being partly
d sodium, and the aluminium by ferricum).
ite from Unionville, Chester county, Pennsylvania. *Cling-*
ral from Buncombe county, North Carolina.
lso a variety of margarite. (Dana, ii. 300. Rammelsberg's

A variety of muscovite or biaxial mica, apparently formed
umption of water, and loss of alkalis and ferric oxide. A
onnecticut, analysed by Smith and Brush (Sill. Am. J. [2]
46·50 per cent. silica, 33·91 alumina, 2·69 ferric oxide, 0·90
potash, and 4·63 water, with 0·82 fluorine and 0·31 chlorine.
he acetone of margaric acid: it has not been prepared from

1. with HAUYNE (p. 14).
hydrous carbonate of zinc, containing 73·26 per cent. ZnO,
ter, found in Marion county, Arkansas (Elderhorst, Sill.
A mineral of the same composition occurs at Cumillas, near
composition is expressed nearly by the formula:
$nO.3CO^2.6H^2O$, or $3ZnCO^3.5ZnO.6H^2O$.
ahresb. 1858, p. 734.)

. An alloy introduced by Wetterstedt in 1833, for the
nsists of 94·4 per cent. lead, 4·3 antimony, and 1·3 mercury;
1·1, is very malleable, but harder than lead. It is said not
r hydrochloric acid, and to be twice as cheap as copper. It
to have been practically used.

W. The law which expresses the inverse proportionality
the pressure to which it is subjected at a given temperature.

OF. The volatile oil obtained by distilling sweet marjoram
Origanum marjorana) with water is lighter than water, and

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contains a considerable quantity of camphor or stear
latter by rectification, it boils at about 161°, and appea
oil of turpentine, containing, according to Kane (Ann.
86·1 per cent. carbon, 11·1 to 11·4 hydrogen, and abou
arising from a small quantity of the camphor not compl
The camphor of marjoram is hard, colourless, i
melts when heated, and sublimes without residue. It
ether, nitric acid, and sulphuric acid, the last colouring
to Mulder (Ann. Ch. Pharm. xxxi. 69), 60·0 per cent.

MARL. See LIMESTONE (p. 698).

MARMATITE. A black ferruginous variety of b
Popayan, South America. (See ZINC, SULPHIDE OF.)

MARMOLITE. Syn. with SERPENTINE.

MARRUBIÏN. (Kromayer, Arch. Pharm. [2]
ciple of white horehound (*Marrubium vulgare*). To p
peatedly exhausted with hot water; the united and co
with recently-ignited animal charcoal; and the charco
well boiled with alcohol, whereby a bitter solution is ob
the greater part of the alcohol by distillation, and then l
marrubiïn as a brown bitter balsam. For purification,
solution is mixed with water till it begins to show turbi
and the filtered liquid, after being freed from lead by s
rate. The marrubiïn then separates in light brownish-
separated from the mother-liquid, solidify in crystallin
marrubiïn, however, assumes the crystalline form; th
resembles the crystallised substance, solidifying in the
marrubiïn also from fresh horehound, the greater part o
amorphous state.

Marrubiïn crystallises from ether in colourless rhon
twin-crystals; from alcohol in needles. It is nearly inso
bitter taste of horehound becomes perceptible after som
soluble in hot water. *Alcohol* and *ether* dissolve it rea
solutions. Marrubiïn melts at 160°, and solidifies crystal
peratures, it gives off white, very irritating vapours. V
distils in oily drops, giving off pungent vapours smellin
sulphuric acid dissolves it with brown-yellow colour: st
act upon it even when heated; strong *nitric acid* does
dissolves it with yellow colour when heated. It is not
or by *metallic salts*, and produces but a slight reduc
silver; neither is it precipitated by *tannic acid*.

MARSH-GAS.—*Light carburetted* hydrogen, *Hyd*
This hydrocarbon gas is very abundant in nature. T
often seen on the surface of stagnant water consist of it
bonic acid. From its occurrence in this way in mars
Great quantities of it are given off by many of the coal
lates in coal pits, where it is known as the *fire-damp* of
the explosions which occur in those places. It is, more
earth in many parts of Italy, Persia, China, and Americ
Besides being one of the usual products of the decay
of their destructive distillation, especially when this ope
temperatures, and in general of the imperfect combusti
proportion of common illuminating gas. Bunsen's analy
34·90 vols. of marsh-gas in every 100 vols. of the gas.
In the laboratory—if we except this production of it
destructive distillation of organic substances—it is comp
prinicipal other reactions which are known to yield it a
(1) The action of nascent hydrogen on tetrachloride o
being generated by the action of potassium-amalgam on

$$CCl^4 + H^8 = CH^4 + 4H$$

(2) The action of zinc-methyl on water, and certain
kind. (Frankland.)

$$(CH^3)^2Zn + 2H^2O = 2CH^3H +$$

From this reaction it derives its name, hydride of m
(3) The action of sodium on iodide of methyl in pre

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stead of yielding pure methyl, gives a large quantity of hydride

phide of carbon upon sulphuretted hydrogen and copper, or iron action of sulphide of carbon on phosphoretted hydrogen and

ason for believing that it is produced by the direct action of hydride at a red heat, since when marble is heated in a current r is generated than corresponds to the simple reduction of the c oxide. (Wanklyn and Frank.)

adiest way of preparing large quantities of marsh-gas in a state the destructive distillation of a mixture of an alkaline acetate

employ 2 parts of crystallised acetate of sodium, 2 parts of caustic powdered quicklime (Dumas, Ann. Ch. Phys. [2] lxxiii. 92). quicklime is to save the retort, which might otherwise be per- tash. In conducting the operation, a little caution is requisite; f until the temperature is very high, and then there is a sudden

the alkali and the acetate is tolerably precise:

$$\left.\begin{matrix}CO\\Na\end{matrix}\right\}O + HKO = \left.\begin{matrix}CO''\\K\\Na\end{matrix}\right\}O^2 + \left.\begin{matrix}CH^3\\H\end{matrix}\right\}$$

of sodium. Carbonate of potassium and sodium. Marsh-gas.

Bunsen's destructive distillation of cacodyl,

$$2As(CH^3)^2 = As^2 + 2CH^4 + C^2H^4,$$

Cacodyl. Marsh-gas. Ethylene.

distillation which yields marsh-gas by a precise reaction. as just described from the acetate is, however, liable to certain rity. It is easy to see how small quantities of acetone-vapour or destructive distillation of an acetate alone gives acetone. gh degree of purity be required, it may be obtained by decom- water.

nds, marsh-gas is the richest in hydrogen, containing as much hydrogen itself it is the lightest gas (specific gravity 0·5576), propriately named *light carburetted hydrogen*. In general eat resemblance to hydrogen. It is incondensable, colourless, neutral to test-paper, and very neutral altogether. It is dis- ner hydrocarbons by the low luminosity of its flame. In *water* sparingly soluble. 100 vols. of water at 0° C. dissolve 5·449 vols. of alcohol at 0° C. dissolve 52·259 vols. (Bunsen). of marsh-gas in alcohol affords a method of separating it arbon gases, such as ethyl, which dissolve in alcohol to a much ans of *sulphuric acid* or *bromine* (neither of which attacks it), ved from a gaseous mixture containing marsh-gas and olefines. tash, and indeed there is no reagent which absorbs it. From arated by means of an ammoniacal solution of *cuprous chloride*. e hydrochloric solution of cuprous chloride, might be employed (see Analysis of Gases, i. 283). According to Dumas, it is not *ulphur*, nor by *pentachloride of phosphorus*, nor by *pentachloride* g to Kolbe, a hot and concentrated mixture of *sulphuric and* ct it. In the dark, dry *chlorine* is without action upon it. A orine with 1 vol. of marsh-gas is not at first visibly affected by ile it explodes. The passage of an electric spark also determines aseous mixture be diluted with carbonic anhydride, and then iet chlorination takes place; and if excess of chlorine be there, oride of carbon are produced (Dumas). Equal volumes of -gas exposed to diffused daylight, give a chlorinated product, ^3Cl. It appears that this compound, CH^3Cl, if not identical is very readily converted into it: for Berthelot has succeeded pounds from it by double decomposition.

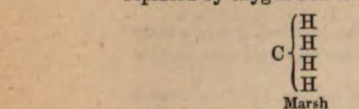
, chlorine converts marsh-gas into hydrochloric acid, carbonic .

sh-gas is resolved into carbon and hydrogen. The same change

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is effected by the transmission of electric sparks, b complete.

Carbon being a tetratomic element, marsh-gas is the the type of a numerous class of compounds which are p or less hydrogen by other radicles. Thus chloride marsh-gas: Methyl-alcohol is marsh-gas wherein hydr oxide of hydrogen: Formic acid is marsh-gas wherein replaced by oxygen and some by peroxide of hydrogen,



Marsh Gas. Chloride of Methyl. Methylic Alcohol.

When carbon makes a partial saturation of itself, as p do, and as carbon of all polyatomic elements is espe complex carbon-groups requiring very various amounts When the carbon has adhered to itself with the least po power, and when the complex carbon-group so resultin gen, there result certain hydrocarbons which form a ve the marsh-gas family. The marsh-gases—homologues by their great neutrality, and present a uniformity of c able.

MARSH'S TEST FOR ARSENIC. See Ar

MARTINSITE. A variety of common salt from chloride of sodium to 1 pt. sulphate of magnesium. 127.)

MARTITE. The octahedral form of native ferri Dome; at Tramont; in Monroe County, New York; crystals are regular octahedrons, often flattened, an striated parallel to the edges. Cleavage indistinct. H = 4·82, Brazil; 4·65, Puy de Dome; 3·80, Peru (Breit Lustre submetallic. Colour iron-black, sometimes w brown, or purplish-brown. Fracture conchoïdal. Not

MARTYLAMINE. Syn. with Xenylamine.

MARUM-CAMPHOR. A camphor or stearopte thyme (*Teucrium Marum*). It is extracted by distillin repeatedly cohobating the distillate over fresh quantiti white, crystalline, transparent, brittle mass, consisting water, having an unpleasant odour and aromatic tast and 87.)

MASCAGNINE. A sulphate of ammonium, (N volcanoes; it was discovered by Mascagni in the fissure and the Lipari Isles. It sometimes forms trimetric cryst 1 : 1·129. Angle ∞P : ∞P = 107° 40′; oP : P̆∞ parallel to ∞P̆∞ ; imperfect parallel to oP. Usuall titic forms. Hardness = 2·25. Specific gravity = 1·7 tallised vitreous. Colour yellowish-grey to lemon-yello gent and bitter. (Dana, ii. 379.)

MASOPIN. $C^{12}H^{18}O^2$. (Genth, Ann. Ch. Pharm. x obtained from a material used in Mexico for chewing. said to be derived from a tree called *Dschilte*, growing crude porous lumps having a dull aspect, but presenting softens between the fingers, has little or no taste when like that of rotten cheese. To extract the masopin, the exhausted by boiling with water; and the soft ropy resi alcohol, which on cooling deposits masopin in crystal separating on addition of water. The portion of the jui of caoutchouc.

Masopin is a snow-white, light, pulverulent substance, passed between the fingers, has neither smell nor ta easily soluble in alcohol and in ether, and crystallises white silky needles or frequently in tufts of small prism emitting an agreeable odour, and the melted mass sol

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ce, having a conchoïdal fracture, and melting again at 69° or

distillation a brown viscid oily mass, having an acid reaction. d by digestion with ammoniacal water, and the remainder then me, a light-yellow mobile oil is obtained, having an agreeable ontaining 88·02 per cent. carbon, and 11·49 hydrogen. The acid ammonia separates, on addition of hydrochloric acid, in nacreous id: it may be further purified by precipitation from solution in zzling-white silver-salt, which burns with an odour of cinnamon, cent. silver oxide.

radually in nitric acid, and the solution leaves on evaporation a ed sugar, which is soluble in water, ammonia, and potash, and e latter, forms dingy yellow precipitates with most metallic salts.

otoxide of lead prepared without fusion. See LEAD, OXIDES OF

PHOR AND OIL. Massoy-bark, obtained from New Guinea, of *Laurus Burmanni*, or of *Cinnamomum Kiamis* (Nees), con- aroptene, and two volatile oils. The camphor is heavier than l, ether, and acetic acid, and coloured yellow by nitric acid. The sinks in water, becomes pasty at 10°, has a pungent taste, and is itric acid. The lighter oil is more volatile, has a stronger odour s lighter than water, dissolves easily in alcohol, ether, and acetic cherry-red by nitric acid. The two oils and the camphor are by distillation with water. (Bonastre, J. Pharm. xv. 204.)

, OIL OF. (Wackenroder, Br. Arch. xxxvii. 341.—Hirzel, .)—The root of masterwort (*Imperatoria Ostruthium*) contains a y be extracted by distilling the comminuted root with water. watery distillate; the rest may be obtained by agitation with and the whole purified by rectification with a small quantity of over chloride of calcium. The yield of oil is from 0·78 to 0·78

ent and colourless (Hirzel), pale yellow (Wackenroder), which distils between 200° and 220° is more viscid). It boils)°; has an aromatic odour (somewhat empyreumatic, between ling to Hirzel); penetrating (Wackenroder); its taste is zel); camphorous like that of poppy-oil (Wackenroder). fuliginous flame.

distils between 170° and 180° contains, according to Hirzel, , 11·45 hydrogen, and 2·98 oxygen; that which distils between s 81·43 carbon, 11·32 hydrogen, and 7·25 oxygen. The oil ap- of several hydrates of a hydrocarbon isomeric with oil of turpen- th the formula $4C^{16}H^{16}.H^2O$ and $3C^{16}H^{16}.2H^2O$. (Hirzel.)

with rise of temperature and evolution of hydrochloric acid gas, d into a yellow viscid oil, which sinks in water, has a peculiar ste. It is decomposed in like manner by *bromine*, with evolution By distillation with *phosphoric anhydride* it yields a transparent as an odour of rosemary and an aromatic taste, and is isomeric e. This latter oil absorbs hydrochloric acid gas, assuming a and forming, after complete saturation, rectification with water, chloride of calcium, an oil which has an agreeable odour, an composition (74·98 C, 10·86 H, 13·28 Cl) agreeing with the (Hirzel.)

n obtained by incisions in the bark of the stem and branches of ree growing in the islands of the Grecian Archipelago, especially nall round transparent grains, having a faint agreeable odour, istinct when the resin is thrown on red-hot coals. It softens is said to strengthen the gums. It is also used in fumigations, and arnishes. Specific gravity = 1·074. According to Schrötter, $I^{32}O^2$.

issolves the greater part of the resin, leaving masticin un- soluble portion, which, according to Johnston, has the composi- ipitated from its solution by chlorine as a viscid mass. When to 145° in the dry state, it is said to be resolved into two other a larger, the other a smaller proportion of oxygen.

ENT. A building cement composed of finely-ground oolitic

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limestone mixed with sand and litharge, and made into linseed-oil. (See CEMENTS, i. 820.)

MASTICIN. $C^{10}H^{31}O^2$, according to Johnston.—T which is the least soluble in alcohol, amounting to $\frac{1}{12}$ – soft at ordinary temperatures, but by prolonged dryin parent, yellowish, and friable, and is said to be then mo

MATICIN. A bitter substance of unknown compos of the matico (*Piper asperifolium*), a plant growing in P a strongly aromatic and slightly astringent taste, are not properties, and especially for their styptic power. When a somewhat considerable quantity of a heavy volatile o in the water, together with several other substances, from by precipitation with acetate of lead. The maticin t water, and may be obtained, by evaporation to a syrup, s ration of the alcoholic solution, as a yellow-brown ext agreeable odour and extremely bitter taste. It is solub soluble in ether. The aqueous solution is not precipit forms a yellow precipitate with potash, and with ammon xxv. 204; Mem. Chem. Soc. i. 123.)

MATICO, OIL OF. To obtain this oil, the leaves tilled with water, and the oil which slowly sinks to the is collected. Pale green, thickish; has a strong and pers camphorous taste. By keeping, it becomes thicker a nitric acid, it is coloured amber-yellow and resinised. forming a carmine-coloured liquid which becomes milky solves readily in alcohol and ether, not in aqueous pot *loc. cit.*)

MATLOCKITE. Oxychloride of lead, Pb^2Cl^2O, fo (p. 335).

MATRICARIA CHAMOMILLA. *Wild cha* plant distilled with water, yield a volatile oil of a dark b with a strong odour of chamomile, and an aromatic burn but thickens when cooled below 0°. (*Gmelin's Handbook,*

MATRICARIA PARTHENIUM. *Feverfew.*—T ing state, yields by distillation with water a greenish c between 165° and 220°, the largest portion, however, dis The oil consists of a hydrocarbon containing about 86 per a camphor having the same composition as that of the la rotatory power (see CAMPHOR, i. 729), and an oxygenate than camphor. (Dessaignes and Chautard, J. Ph Compt. rend. xxxvii. 166.)

MAUILITE. Syn. with LABRADORITE (p. 450).

MAYNAS RESIN. *Calaba* or *Galba* of the Antill x. 380). A resin extracted by incision from *Calophyllum* on the plains of San Martino and of the Oronoco. It pos racters of resins, but when purified by solution in alcohol parent prisms, and is obtained by slow crystallisation i fine yellow colour. According to Provostaye, they are m bination ∞P. $\infty P\infty$. $[\infty P\infty]$. oP . + P . $P\infty$. $[P\infty]$. ∞P : oP = 101° 7′; oP : $[P\infty]$ = 143° 15′: ∞P : [: $P\infty$ = 139° 35′; $\infty P\infty$: ∞P = 150° 30′. Ratio of axe Angle of axes b and c = 78° 43′.

Maynas resin has the characters of an acid, dissolvi temperatures, in potash, soda, and ammonia. It is insolu *alcohol*, *ether*, and *oils* both fixed and volatile. Specific about 105° to a transparent glass, and when once melt time, not solidifying till cooled to about 90°. By *dry* matic oils, and leaves a carbonaceous residue. It con of Lewy's analyses, 67·52 per cent. carbon and 7·30 hyd the formula $C^{14}H^{18}O^4$ (calc. 67·2 C, 7·2 H, and 25·6 O).

The resin dissolves in cold *acetic acid*, also in *sulphuri* fine red colour, from which it is precipitated by water strongly acted upon by fuming *nitric acid*, yielding a With ordinary nitric acid it forms a volatile acid exhibiti acid; the solution yields, by concentration, crystals of ox

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ich has not been determined. The resin heated with a mixture
otassium and *sulphuric acid*, gives off carbonic anhydride and
and *bromine* act upon it, but without yielding definite products

FRON. *Gratiola officinalis* (ii. 942).

ET. See SPIRÆA.

ID. A crystalline acid produced, together with a chlorinated
chlorine on meconin. It contains 48·72 per cent. carbon, 4·07
e; crystallises in fine prismatic needles; is soluble in potash,
ld, easily in boiling water.

ACID. See MECONIC ACID, AMIDES OF.

). $C^7H^4O^7 = \left.\begin{matrix}C^7HO^4\\H^3\end{matrix}\right\}O^3$. *Mohnsäure. Opiumsäure.*—This acid
constituents of opium, was discovered by Sertürner in 1803
i. 183; lxiv. 65), but the more exact investigation of it has been
iquet (Ann. Ch. Phys. v. 282; li. 236; liii. 425), and Liebig
37; xxvi. 113, 147).
f preparing it is that of Robiquet, modified by Gregory
v. 43). Opium is exhausted with water at 38°; the extract is
ly pounded marble, evaporated to a syrup, and mixed with a con-
hloride of calcium, whereby the meconate of calcium is more com-
roportion as the liquids are more concentrated; and the preci-
water and pressed. [The mother-liquor serves for the preparation
f the precipitated meconate of calcium is now suspended in a
mercial hydrochloric acid and 20 pts. boiling water; the mixture
e short of 100°, and frequently shaken, till the whole is dissolved;
of calcium which separates on cooling is collected on linen, washed
of water, and redissolved, after pressure, in a mixture of 3 pts. of
20 pts. of hot water, avoiding ebullition. The liquid then yields, on
conic acid nearly free from lime, while the mother-liquor, in con-
of hydrochloric acid, contains scarcely any meconic acid. The
after being washed and pressed, are dissolved in 16 pts. of hot
ained through linen; and the filtrate is mixed with two-thirds of
f hydrochloric acid; on cooling it yields crystals of meconic acid,
l coloured. These crystals are suspended in cold water, neutra-
potassium, and heated to 100° with gradual addition of water in
to dissolve them; the solution, which solidifies on cooling, is well
ch runs off yields impure meconic acid when treated with excess
the expressed mass, which is not yet quite white, is redissolved
e quantity of boiling water; the solid mass obtained on cooling
this treatment is repeated till a pure white product is obtained.
nate of potassium is dissolved in 16 to 20 pts. of hot water; the
sium which separates on cooling is mixed on linen with a small
pressed, and redissolved in 16 pts. of hot water; the solution is
of hydrochloric acid; and the crystals of pure meconic acid
are washed with cold water, and recrystallised from solution in
quantity of boiling water. The mother-liquor expressed from
l yields a quantity of impure meconic acid when treated with
aper-filters [probably on account of the iron contained in them]
part of the process.
harm. lxxxiii. 350) heats the crude acid free from lime with
water, till the whole dissolves on addition of ammonia. The
difies in a crystalline mass, which may be freed by pressure from
r, and recrystallised two or three times from the smallest possible
ter. From the solution in hot water, the meconic acid separates,
f hydrochloric acid, in colourless laminæ, which are washed with
ecrystallised from boiling water.
of opium might also be treated in the first instance with ammonia
rphine, and the meconic acid afterwards precipitated by chloride
onia always precipitates a certain quantity of meconic acid from
n the form of a calcium-salt: hence the process is attended with

llises in micaceous scales or small rhombic prisms, containing
$3H^2O$), which it gives off at 100°, leaving a white, opaque,
s a sour taste, and reddens litmus strongly. It dissolves readily
ess easily in *ether*.

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Meconic acid is resolved, under various circumstances, comenic acid:

$$\underset{\text{Meconic acid.}}{C^7H^4O^7} = CO^2 + \underset{\text{Comen acid.}}{C^6H^4O}$$

the latter frequently undergoing further transformation is *heated* to about 120°, carbonic anhydride is given o behind; at higher temperatures, the comenic acid is fur bonic anhydride and pyromeconic acid, $C^5H^4O^2$, partly i reumatic oil, and charcoal.—2. When meconic acid is *hydrochloric acid*, a brown colouring matter being also 3. By the action of *chlorine* or *bromine*, in presence of wate anhydride and chloro- or bromo-comenic acid.—4. By bo the comenic acid being then converted into comenami *iodide of ethyl*, whereby carbonic anhydride is given produced.

Meconic acid is easily oxidised by *nitric acid*, yieldi acid.—By boiling with strong caustic *potash* also, it yie carbonic anhydride and a brown substance.—By *chlorid* converted into iodomecone, $C^5HI^4O^2$. [? impure iodofor

The aqueous solution of meconic acid is coloured de colour not being destroyed by boiling, or by the action of

Meconates.—Meconic acid is tribasic, and forms thre

Acid.

monometallic.	dimetallic.
$C^7H^3MO^7$	$C^7H^2M^2O^7$

The dimetallic meconates are neutral to vegetable colours

Meconates of Ammonium.—The *tri-ammonic salt* *salt*, $C^7H^2(NH^4)^2O^7$, crystallises in slender needles. On solution, the *mono-ammonic salt*, $C^7H^4(NH^4)O^7.H^2O$, se sparingly soluble in cold water.

Meconates of Barium.—The *dibarytic salt* is Chloride of barium forms, with solutions of the alkaline m in acetic acid. Aqueous meconic acid forms with bary cipitate, probably consisting of *tribarytic meconate*.

Meconates of Calcium.—The *monocalcic salt*, $C^{14}H$ by chloride of calcium from aqueous meconic acid, and f even of neutral meconates.—The *dicalcic salt*, $C^7H^2Ca''O^7$ gelatinous precipitate, on adding chloride of calcium to saturated with ammonia.

Meconates of Copper.—The monocupric salt is ob precipitate on adding meconic acid to a solution of cupric it yields a large quantity of pyromeconic acid. Mecon emerald-green precipitate with cupric acetate.

Meconates of Iron.—α. The *ferrous salt* is very sol exposure to the air, and more quickly when mixed with n

β. *Ferric salt.* Soluble meconates added to ferric salt a deep blood-red liquid, without precipitation, even when t but when neutral ferric sulphate is treated with meconate coloured pulverulent precipitate is formed after a while, cold water and in alcohol, easily in boiling water and in aqueous solution with potash, ferric oxide is precipitated, red colour disappears; if hydrochloric acid be then add alkali, the red colour reappears, but is again destroyed by cipitate, if previously dried in the air at ordinary tempera at 100°. Stenhouse found in five samples of it, dried cent. carbon, 2·1 to 2·5 hydrogen, 3·4 to 3·5 nitrogen, a On mixing solutions of meconic acid and ferric chloride i flocks very soluble in cold water are precipitated. Sten rations (at 100°) from 25·3 to 25·9 per cent. carbon, 1·7 31·2 ferric oxide.

Meconates of Lead.—The *neutral salt*, $C^{14}H^2Pb^3O^{14}$, tating neutral acetate of lead with meconic acid, even flocks, insoluble even in boiling water.

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ing from 68·4 to 78·4 per cent. lead-oxide, are obtained by pre-
e of lead with alkaline meconates.

ts.—The *dimagnesic salt* is sparingly, the monomagnesic salt
; the latter crystallises in shining, transparent, flattened needles,
tter taste.

ercury.—Both the mercurous and mercuric salt are pale yellow
, insoluble in water, soluble in nitric acid.

otassium.—The *acid salts* are crystallisable, the *neutral salt*

lver.—Aqueous meconic acid forms with nitrate of silver a white
rgentic salt, $C^7H^2Ag^2O^7$, which, by prolonged boiling with water,
tri-argentic salt, $C^7HAg^3O^7$. The latter is also formed, as a
mixing a solution of meconic acid, exactly saturated with ammo-
alt) with nitrate of silver.

odium.—The *monosodic salt* forms hard grains, but slightly
e *disodic salt*, obtained by digesting meconate of barium with
odium, crystallises in slender needles, soluble in 5 pts. of water,
quantity of water of crystallisation. The *trisodic salt* is crys-
in water, and efflorescent.

in.—The *stannous salt* is a white precipitate, very soluble in
solution. The *stannic salt* is also a white precipitate, sparingly
y in nitric acid.

rium.—Sparingly soluble in water; yttrium-salts, however, give
econic acid.

D, AMIDES OF. By acting on ethyl-meconic acid and diethyl-
monia, How has obtained two acids, which may be regarded as
ate *minus* water, viz.:

. . . . $C^7H^5NO^6 = C^7H^3(NH^4)O^7 - H^2O$
acid . . . $C^7H^6N^2O^5 = C^7H^2(NH^4)^2O^7 - 2H^2O$

ds has, however, been obtained in the crystalline form, and their
t doubtful. To the former How assigned the somewhat impro-
N^7O^{36}; the formula above given was proposed by Gerhardt.

IERS. Meconic acid, being tribasic, should form three ethers
ther alcohol-radicles. Only the two acid ethyl-meconates are,
nown.

CID, $C^7H^3(C^2H^5)O^7$, is obtained by passing dry hydrochloric
olution of meconic acid in absolute alcohol, till the liquid emits
ft at rest, deposits the ethylated acid in needle-shaped crystals,
l by recrystallisation from hot water.

ll needles very soluble in boiling water, soluble in ether and in
rength, less soluble in absolute alcohol. The crystals are anhy-
nd sublime in brilliant rhombs.

is dibasic, forming two series of very stable salts, viz. *neutral*
, and *acid salts*, $C^7H^2M(C^2H^5)O^7$. They crystallise readily.
rm. lxxxiii. 350.)

ACID, $C^7H^2(C^2H^5)^2O^7$, is contained in the mother-liquor from
acid has separated, and may be obtained by evaporating this
acid vapours. The residue is a thick oil which solidifies on
urified by recrystallisation.

olourless prisms, melting at about 110°; it melts in boiling water
l dissolves very easily in alcohol. Its aqueous solution has a
decomposes carbonates, and rapidly coagulates albumin. It
l.

basic, the formula of its salts being $C^7HM(C^2H^5)^2O^7$. The
llises in yellow needles, and is very soluble in cold water. It
red by passing gaseous ammonia into an alcoholic solution of
n-salt is a yellow semi-gelatinous precipitate, insoluble in boiling
e in excess of chloride of barium. The *strontium-* and *calcium-*
ium-salt. The *magnesium-salt* is a crystalline precipitate. The
nd gelatinous. The *lead-salt* is a yellowish-white precipitate.
w, gelatinous, insoluble in boiling water. (How, *loc. cit.*)

anyl. $C^{10}H^{10}O^4$.—A neutral substance existing in opium. It was
blanc (Ann. Ch. Phys. [2] xlix. 17); afterwards prepared in
xamined by Couerbe (*ibid.* xlix. 11; l. 337; lix. 148).

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It is produced from narcotine, together with tero
and hemipinic acid, by the action of warm dilute
Trans. xx. 347; xxi. 204), and from opianic acid by
nascent hydrogen, evolved either by the action of soc
on dilute sulphuric acid. (Matthiessen and Fos

α. Action of alkalis:

$$\underset{\text{Opianic acid.}}{2C^{10}H^{10}O^5} = \underset{\text{Meconin.}}{C^{10}H^{10}O^4} +$$

β. Action of nascent hydrogen:

$$\underset{\text{Opianic acid.}}{C^{10}H^{10}O^5} + H^2 = \underset{\text{Meconi}}{C^{10}H^{10}}$$

Preparation. *a. From Opium.*—1. Finely cut
cold water; the filtrate is evaporated to 8° Bm., and
precipitated by dilute ammonia. The filtrate evapo
several weeks in a cool place, deposits brown crystal
dried at a gentle heat. The brown crystalline mass
other substances. It is exhausted with boiling alc
concentrated to one-third by distilling off the alc
deposits crystals, which are purified by recrystallisat
tion of animal charcoal, then from hot ether. Th
crystals have separated, yields an additional quanti
(Couerbe.)

2. The aqueous extract of opium is precipitated by
tated meconate of calcium is filtered; the filtrate ev
and separated from the deposited hydrochlorate of mor
is diluted with water, filtered from the flocks which s
which precipitates narcotine, thebaine, and a large
mixed with acetate of lead; the excess of lead is re
dilute sulphuric acid; and the filtrate is neutralised
the crystallising point at a moderate heat, whereupo
sal-ammoniac by further concentration. The mother
½ vol. ether at 26°, and the ether is distilled off fro
remaining. On treating this syrup with dilute hydro
and meconin remains in the form of a dark grey cr
from resin and purify it completely, must be sever
water, with addition of animal charcoal. (Anders

b. From Narcotine.—Narcotine is heated in the
nitric acid of specific gravity 1·4, and 8 pts. water, w
mass, dissolves slowly without evolution of gas,
gradually deposits crystalline teropiammone. The l
the filtrate saturated with potash-ley; the solution
cotarnine, and concentrated to a small bulk; cryst
mother-liquor freed from carbonate of potassium b
alcohol is distilled off; and the cooled residue treated
cipitates opianic acid, hemipinic acid, and meconin.
a large quantity of boiling water, meconin crystallis
little opianic acid, if the quantity of water added was
by recrystallisation from water or alcohol. (Ander

c. From Opianic acid.—1. By the action of stro
preparation is described under Hemipinic Acid (p. 1
hydrogen. Sodium-amalgam is warmed for several
opianic acid; and the meconin is precipitated from
The formation of the meconin in this case is not due
formed from the sodium-amalgam: for it takes pla
temperature very much below that at which opiani
influence of alkali; the quantity of meconin formed
that which is produced under the latter circumstan
posed by sodium-amalgam having yielded 3·65 g
according to the first of the two equations above give
alkalis, yield only 2·3 grms. meconin. Moreover, opia
meconin by the action of zinc and dilute sulphuric aci

Properties.—Meconin crystallises in hexagonal pr
is perfectly colourless; has no smell; and appears ta
acrid taste as it dissolves in the mouth.

It melts at 90° (Couerbe); between 98° and 99°
which retains its fluidity till cooled to 75°. At a high
without alteration, solidifying to a fatty mass on cool

A hydrate of meconin was once obtained by An

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embled the anhydrous compound, but was lighter, and did not

n 265·7 pts. of cold, and 18·5 pts. of boiling *water;* in *alcohol* ore soluble. It is dissolved by the *fixed alkalis*, but is nearly When heated to 100° with aqueous *ammonia*, it yields a solu- orated over sulphuric acid at ordinary temperatures, but from pitated on addition of water (Matthiessen and Foster).—Its itates *basic acetate of lead*, but not the neutral acetate.

thout alteration in *dilute sulphuric acid*, forming a colourless dark green when evaporated: if alcohol be then added, the olour; but as the alcohol evaporates, the green tint returns. osits brown flocks when mixed with water (Couerbe). With neconin forms a colourless solution which becomes purple when ddition of water, depositing at the same time a brown precipi- th rose colour in alkalis. *Nitric acid*, either dilute or concen- in into nitromeconin, with evolution of red vapours. With *ute sulphuric acid*, it gives off carbonic anhydride, and forms an hich remains dissolved.

in forms chloromeconin (Anderson). According to Couerbe, y on meconin at common temperatures, but is rapidly absorbed orming a red and then a dark brown mass, which melts at a n meconin, and forms on cooling a crystalline mass containing meconin-resin, and 25·5 per cent. chlorine. Meconin is not hen treated with *chloride of iodine*, it forms iodomeconin. With bromomeconin.

ithout alteration in cold *hydrochloric* acid; but when heated ght of strong hydrochloric acid to 100° in a sealed tube, it is ation of an acid containing $C^9H^8O^4$, and separation of chloride ly volatilises when the tube is opened: $C^{10}H^{10}O^4 + HCl =$ thiesen and Foster, *unpublished experiments*). A similar ed by *hydriodic acid*. From these results Matthiessen and econin is a methylated compound; and although the propor- d in it has not been experimentally determined, they infer, her derivatives of narcotine (*q. v.*) that its rational formula is

to say, that it is the dimethylated derivative of a compound,

t isolated, which may be called normal meconin.

Substitution Derivatives of Meconin.

$^{10}H^9BrO^4$.—When bromine-water is gradually added to aqueous momeconin separate out, and may be purified by recrystallisa- l. It forms colourless needles, which melt at 167°, and behave loromeconin. It dissolves sparingly in *water*, more readily in derson, Ann. Ch. Pharm. xcviii. 48.)

$C^{10}H^9ClO^4$. When chlorine-gas is passed into a cold saturated onin, an abundant crop of crystals quickly separates, consisting may be purified by recrystallisation from alcohol. It is like- chlorine-gas is passed over melted meconin. It crystallises hich melt at 175°, and sublime undecomposed at higher tem- sparingly in cold, somewhat more freely in boiling *water;* in e amount as in water, and without decomposition. It is soluble

sulphuric acid, assumes a greenish-blue colour when heated quent addition of water, deposits brown flocks which dissolve alis. It dissolves with red colour in *nitric acid*, and is decom- ewith. (Anderson, Ann. Ch. Pharm. xcviii. 47.)

$^9H^9IO^4$.—When chloride of iodine is added to aqueous meconin, itself for several days in a warm place, long crystals form in it, iodine. They are purified by recrystallisation from boiling

colourless needles, which melt at 112° to a colourless liquid. in *water*, more soluble in *alcohol* and *ether*. It melts at a ° to a brown liquid, which decomposes at a stronger heat with It dissolves in *sulphuric acid*, forming a dark-coloured liquid ecomposed by *nitric acid*, with separation of iodine. (Ander-

$^{10}H^9NO^6 = C^{10}H^9(NO^2)O^4$.—Meconin dissolves abundantly in

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cold concentrated nitric acid, the solution giving off red fumes diluting with water, bulky crystals separate, which may be obtain and recrystallisation from boiling alcohol.

Nitromeconin forms white needles and prisms, melting at 16 liquid, which solidifies in the crystalline form on cooling. It sparingly in cold, somewhat more freely in boiling *water;* it is insol *acid*, but dissolves in cold strong *nitric acid*, separating in flocks diluted. In cold *ammonia* and *potash*, it is not more soluble than precipitated by metallic salts. It dissolves in boiling *alcohol* and

Heated in small quantities on platinum-foil, it volatilises almo sition, leaving only a small quantity of charcoal; but, if heated decomposes suddenly, and leaves a large quantity of porous ch *ammonia* or *potash*, it forms, without decomposition, a yellow solu deposit anything on cooling or on addition of acids.

MECONIUM. A substance occurring in the intestinal cana voided soon after birth: it consists, in fact, of the bile of the fœtus poured into the intestines, and has there undergone a certain a It is a pitchy substance, of a dark brown-yellow colour, and the c Its odour is for the most part faint, and only occasionally unpleas and slightly sweet. It stains linen permanently yellow. In wat bulky mass, in which the microscope shows epithelium-cells, probably consisting of decolorised blood-corpuscles, and a consi rhombic tablets of cholesterin. According to Simon, dried meconi cholesterin, 10·4 extractive matter and bile-resin, 34 casein, 6 pi 26 cells, mucus, and perhaps albumin (= 96·4). The cholesterin is the extractive matter and bile-resin by alcohol. Aqueous alcohol together with picromel; the biliverdin may be dissolved out by alc sulphuric acid.

According to John Davy, meconium contains 72·7 pts. of wat epithelium-cells, 7·0 cholesterin and margarin, and 3·0 olein an matters.

When burnt, it leaves an ash consisting chiefly of ferric oxide traces of calcic phosphate and sodic chloride. According to Payen, salt, alkaline carbonate and calcic phosphate. (Handw. d. Chem.

MEDICAGO SATIVA. *Lucern.*—The composition of the determined by Way and Ogston, is given under FODDER (ii. 680).

MEDICINIER, OIL OF. This oil, obtained by expressio *Jatropha Curcas*, is white, scentless, has a density of 0·91 at 19° buttery mass at − 8°. It is nearly insoluble in alcohol, has a sweet very little on exposure to the air. It is not easily saponified easily converts it into a hard white soap, containing oleic and iso acid converts the oil into suberic acid: pernitric oxide does not so When heated with ammonia, in a sealed tube, it is converted into

MEDJIDITE. Calcio-uranic sulphate, occurring near Adr PHATES.)

MEDULLIC ACID. $C^{21}H^{42}O^3$.—A fatty acid produced, tog palmitic acids, by the saponification of beef-marrow. It forms acid mixture thus obtained. Melting point 72·5°. (Eylerts, Arch.

MEDULLIN. A name applied by Braconnot to cellulose ob or medulla of certain plants.

MEERSCHAUM. (*Sea-foam:* from its apparent lightness A hydrated silicate of magnesium, $2MgO.3SiO^2.2H^2O$, or Mg^2Si^3O stratified earthy or alluvial deposits on the plains of Eskihi-sher, i in Greece, at Hrubschitz in Moravia, and in Morocco. It is com touch, and of fine earthy texture. Hardness = 2 to 2·5; impressibl opaque and white, sometimes with a greyish, yellowish, or red heated in a tube, it gives off water, blackens, and emits a burnt blowpipe on charcoal it burns white, and melts on the thinnest e readily in borax to a transparent glass, and exhibits a lilac colour Hydrochloric acid dissolves it, with separation of silica.

Analyses.—1. is by Lychnell (Kongl. Vetensk. Acad. Förhandl 2. By Damour (Ann. Ch. Phys. [3] vii. 316):

	SiO^2	MgO	H^2O	Fe^2O^3	Al^2O^3	CaO	K^2O
1. Asia Minor	60·87	27·80	11·29	0·09		. .	.
2. Morocco .	55·00	28·00	10·35	1·40	1·20	1·01	0·52

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given requires 60·9 silica, 26·1 magnesia, and 12·0 water. In
neral was first dried over sulphuric acid to expel hygroscopic
porous, it contains a considerable quantity), and the combined
off by heat. The mineral is often mixed with more or less
m, by the decomposition of which it appears to have been
t h, Sill. Am. J. [2] vii. 286.)

erman name for the heaps or stacks of timber piled up for burn-
e CARBON, i. 760.)

btained by Reinsch from *Athamanta Meum*. The root, after
vater, is treated with alcohol of 70 per cent.; the alcohol is
, and subsequent spontaneous evaporation; and the residue is
hich extracts the meïn. On evaporating the ether, the meïn
ow, inodorous, combustible oil, having a burning taste, and not
position. (*Handwörterbuch.*)

. A variety of chlorobromide of silver from Chile, crystallised
ns containing $Ag^9Br^5Cl^4$, or 4AgCl.5AgBr. (See SILVER.)

alcio-aluminic silicate from Somma, where it occurs in small
des, usually in limestone blocks. Ratio of the principal to the
439. Angle P : P in the terminal edges = 136° 11′; in the
; these angles are nearly the same as those of scapolite (*q. v.*).
∞P∞ . ∞P . P . ∞P3 . P∞ . 3P3 . oP Sometimes hemihedral
lternate ones being wanting. Cleavage parallel to ∞P∞ and
often interrupted.

Specific gravity = 2·5 to 2·74. Lustre vitreous. Colourless to
translucent; often cracked within. Before the blowpipe it
ss; forms also a clear glass with soda. According to v. Rath,
dissolves completely in moderately strong hydrochloric acid;
rating the solution, the silica separates in the pulverulent form.
and Kobell, it gelatinises with hydrochloric acid.

elin (Schw. J. xxv. 36; xxxv. 345).—*b.* Stromeyer (*Unter-*
Wolff (*De compositione Eckebergitis, Scapolithi et Mejonitis*,
43).—*d.* Rath (Pogg. Ann. lxxxii. 288).

$^2O^3$	FeO	CaO	MgO	Na^2O*	K^2O	Loss by ignition.	
.	1·07	20·64	. .	2·57	. .	. . =	100·93
.	0·18	24·24	. .	1·81	. .	. . =	99·49
.	. .	22·43	. .	0·45	0·31	0·31 =	97·28
41	. .	21·41	0·83	1·25	0·93	0·19 =	98·46

* With some lithia.

o the formula $3(2CaO.SiO^2) + 2(2Al^2O^3.3SiO^2)$, or $Ca^6Al^8Si^9O^{36}$,
Al, may be reduced to an orthosilicate, R^4SiO^4. (Dana, ii. 200.
lchemie, p. 714.)

Native cupric oxide, found at Copper Harbour, Kewenaw
68).

ame is given by Bizio to the black substance which is deposited,
nates of calcium and magnesium, when the dried residue of the
fish is stirred up with water. It is contained in a peculiar
ls eject on the approach of their enemies, to render the water
ined pure by boiling the above-mentioned residue with water,
with hydrochloric acid, and washing with water containing
mmonium. It is insoluble in water, alcohol, and ether, but
ater for a long time. It dissolves in strong nitric and sulphuric
c or acetic acid. Strong caustic potash dissolves it, forming a
n is precipitated by sulphuric and hydrochloric acids. It is
e carbonates. These characters are very similar to those of
eye. (Handw. d. Chem. v. 160.)

EUCODENDRON. The tree which yields cajeput-oil

or $C^3N^6H^6$? (Liebig, Ann. Ch. Pharm. x. 10; liii. 240.—
—Völckel, Pogg. Ann. lxi. 367; lxiii. 90.—Gerh. i. 464.)—
a residue when sulphocyanate of ammonium is heated. This
perature a little above the boiling-point of water, first giving

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off ammonia, then sulphide of carbon in consid
ammonium, and leaving a residue which Liebig calls
duct with moderately strong potash-ley, till the gre
the filtered liquid to cool, melam is deposited in th
Instead of sulphocyanate of ammonium, Liebig find
equal parts sal-ammoniac and sulphocyanate of po
more vapours of sulphocyanate of ammonium are e
sublime. The mass is then exhausted with cold w
gently ignited.

Völckel prepares melam by heating sulphocyanat
ing the residue with cold water, and then with b
deposit a bulky matter; the last, on cooling, yie
powder.

Melam is a white granular powder insoluble in
ether. It yields by analysis the following numbers

Carbon	
Hydrogen	
Nitrogen	

Liebig deduces from his own analysis the formula
hydrogen); according to which, melam may be reg
$C^6N^6\left\{\begin{matrix}\\H^9\end{matrix}\right\}N^5$, or as a compound of 2 at. tricyanimide v
Gerhardt, on the other hand, prefers the formula
Völckel's analysis (calc. 28·57 carbon, 4·76 hydr
melam as isomeric or polymeric with melamine o

By prolonged boiling with caustic alkalis, melam
separates on evaporation or as the liquid cools. T
which may be precipitated by acids, together with
continued action of the alkali, is ultimately resolve
These changes may be represented by the following

(1, *a.*) . .	$C^6N^{11}H^9$ (Melam.)	+ $2H^2O$
or (1, *b.*) . .	$C^3N^6H^6$ (Melam.)	+ H^2O
(2.) . . .	$C^3N^5H^5O$ (Ammeline.)	+ H^2O
(3.) . . .	$C^3N^4H^4O^2$ (Ammelide.)	+ H^2O

If Gerhardt's formula of melam be admitted, the
mere polymeric transformation: according to Liebi
melamine is produced by assumption of ammonia
other products above mentioned:

$$\underset{\text{Melam.}}{C^6N^{11}H^9} + NH^3 =$$

Melam is resolved by *heat* into ammonia and mellon
($C^6N^{11}H^9 = 2NH^3 + C^6N^9H^3$). When boiled with di
or when treated with nitric acid, it yields ammeline
the same, together with ammelide. By boiling with s
cyanuric acid; and by fusion with hydrate of potass

According to Völckel, melam absorbs hydrochlor
$C^3N^6H^6.HCl$.

MELAMINE. $C^3N^6H^6$.—Syn. with CYANURA

MELAMPYRIN or **MELAMPYRITE.**

MELANASPHALT. A kind of bituminous

MELANCHLOR. A blackish-green phosphat
ing in 100 pts. 38·9 per cent. ferric and 3·87 ferro
and 9 to 10 per cent. water. (Fuchs, J. pr. Chem.

MELANGLANCE. Native sulphide of silve

MELANHYDRITE. A mineral found in t

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elzerthal, near Honnef on the Rhine. It is deposited in the ar particles, of conchoïdal fracture; opaque, with velvet-black, k colour, and blackish-brown streak; small lumps adhere to all to pieces in water. Specific gravity = 1·820. Rammels-

O^3	FeO	MnO	MgO	CaO	H^2O
36	7·83	2·51	5·23	1·67	30·71 = 100·66;

$0.2R^2O^3.6SiO^2.12H^2O$, showing that the mineral is related in . (Krantz, Jahresb. 1859, p. 795.)

$C^{10}H^8O^5$. (Piria, Ann. Ch. Phys. [2] lxix. 281.)—A black her with acetate of potassium, by the oxidation of salicylide ound, when exposed in a slightly moist state to the air, ots, which are green at first, but ultimately become quite ot take place in an atmosphere free from oxygen; but if the er a bell-jar filled with oxygen, the whole of that gas is o other gas is evolved.

presented by the following equation:

$$C^{14}H^6O^4 + O^3 + 2H^2O = \underset{\text{Melanic acid.}}{C^{10}H^8O^5} + \underset{\text{Acetate of potassium.}}{2C^2H^3KO^2}.$$

ion is complete, a carbonaceous mass remains, from which otassium, while melanic acid remains undissolved in the form amp-black. It is tasteless, insoluble in water, very soluble aline liquids, and precipitated from the latter by acids. It nates.

nalysis 56·26 and 56·56 per cent. carbon, and 4·01 hydrogen: res 59·69 carbon, 3·84 hydrogen, and 38·47 oxygen.

ng nearly the same composition is obtained by the action of

n is obtained by digesting melanic acid with ammonia. black precipitate containing 27·27 per cent. carbon, 1·95 r.

ee ANILINE, DERIVATIVES OF, under PHENYLAMINES.

ack pigment of the eye (ii. 615).

ack calcio-ferric garnet (ii. 772), found chiefly near Albano bourhood of Rome.

IDE. $C^{14}H^{11}N^3O$.—A substance probably formed by the imide (*q. v.*).

A doubtful product, formed, according to Brandes and 259), together with several others, by the action of ammonia (*q.v.*).

E. A basic chromate of lead, $PbO.4PbCrO^4$, found at 4).

ACID. Syn. with METAGALLIC ACID.

mineral having the aspect of chlorite, from Milk Row , Massachusetts. It is black and opaque, with a striated umnar structure. Streak dark olive-green. Hardness = 2. According to H. Wurtz, it contains 30·86 per cent. silica, oxide, 21·97 ferrous oxide, 1·62 soda, and 8·94 water, with m = 100·33. This composition, deducting the calcic car- ed by the formula $2(MO.SiO^2).R^2O^3.SiO^2 + 3H^2O$; but the f constant composition (Dana, ii. 288). Rammelsberg serves that it is near Hisingerite.

$C^{15}H^{14}N^3O^2$.—A product of the decomposition of cyano- LINE, under PHENYLAMINES.)

Native ferrous sulphate. (See SULPHATES.)

CID. See CYANURAMIC ACIDS (ii. 287).

e name given by Von Buch to a porphyritic rock, consisting ey matrix of labrador and augite, in which are imbedded als, and sometimes, as accessory constituents, uniaxial mica, tes. It sometimes has the structure of almond-stone, with

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spherical and almond-shaped nodules of calcspar, zeolites, &c
the Alps, especially in the Fassa valley, and near Klausen, in
Lower Rhine, on the Fichtelgebirge; at Friedrischrode, in the
at Holmestrand, in South Norway.

MELASSIC ACID. A black acid, produced, together wi
by heating glucose with caustic alkalis. When glucose is mel
saturated solution of baryta is added, a very violent action take
the first instance to the formation of glucic acid; but if the m
some time to a high temperature, it becomes continually dark
quence of the formation of melassic acid. On dissolving the
precipitating by hydrochloric acid, melassic acid is deposited in
in water, but soluble in alcohol. It contains, according to
to 61·0 per cent. carbon, and 5·3 to 5·4 hydrogen. The formu
61·9 carbon, 4·3 hydrogen, and 33·8 oxygen, agrees with these
carbon is concerned; but the amount of hydrogen found by e
for it.

MELENE. $C^{30}H^{60}$. *Paraffin of Wax.* (Ettling, Ann.
Lewy, Ann. Ch. Phys. [3] v. 395.—Brodie, Ann. Ch. Pharm
stance homologous with ethylene, &c., produced by the dry di
myricyl and of myricin. It may be prepared by subjecting bees'-
treating the product with potash, to saponify the fatty acid for
decanting the soap from the mixture of melene and oily hydroc
this mixture, which then gives off, first, the oily hydrocarbons,
when the heat is considerably increased. The product is purifi
crystallisation from boiling ether. It is generally necessary, h
lising it, to rectify it over caustic potash, in order to remove
oxygenated substance with which it is still contaminated.

Melene crystallises in perfectly white nacreous scales, inodo
specific gravity 0·89. It melts at 62° (Brodie), at 33·5° (Ettli
and solidifies in a waxy mass on cooling. Boils between 370
density, by three experiments, between 10·0 and 11·8: the dete
ever, rendered inaccurate by partial decomposition. It is inso
cold alcohol, but dissolves in boiling alcohol, and easily in ether,
and volatile.

Melene is not attacked by *potash* or *soda*, even at the boiling
does not attack it at ordinary temperatures; but on applying h
is carbonised, while the rest sublimes. It is but slightly attacke
Chlorine attacks it, producing, under certain circumstances, a bo
derable amount of chlorine.

Related to melene are the several mineral tallows, distinguish
hatchettin, *ixolyte*, *kœnlite*, *ozokerite*, *scheererite*, *&c.*

MELENE, SULPHIDE OF. This name was applied b
retted residue obtained, together with others (called respective
xanthene, *xuthene*, &c.), by the action of heat on persulphocyani
are yellow or brown powders varying in composition according
applied, and are probably mere mixtures. (See Gmelin's *Ha*

MELETIN. This name is given by W. Stein (J. pr. Ch
substance produced, together with glucose, by the action of acid
stance, according to most authorities, is identical with quer
according to Stein, it differs from quercetin, and has the com
forms yellow crystals which act on polarised light, and reduce
(See QUERCETIN and RUTIN.)

MELIN. See RUTIN.

MELINOPHANE. A mineral from the zircon-syenite of
to leucophane. The crystals are optically uniaxial, but it has
whether they are dimetric or hexagonal. It also occurs mas
sometimes foliated structure; cleavable in one direction. H
gravity = 3·0. Lustre vitreous. Colour, sulphur-, citron-,
phosphorescent. Brittle. It contains, according to an approxim
44·8 per cent. silica, 2·2 glucina, 12·4 alumina, 1·4 manganic o
31·5 lime, 0·2 magnesia, 2·6 soda, 2·3 fluorine, and 0·3 nicke
oxide, and yttria.

MELITOSE. $C^{12}H^{22}O^{11}$.—A kind of sugar discovered i
con (p. 822) by Bonastre, and further investigated by Berth
[3] lv. 282). The extract of this substance prepared with bo

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evaporated to a syrup, and left to stand for several weeks; the
ed by recrystallisation from boiling alcohol.
ry small, short, hard, shining crystals, resembling those of cane-
scope, white and mealy when seen in mass; it effloresces readily
ir, and gives off 4 per cent. of water when heated; melts below
alteration, and solidifies to a glass on cooling. It is about as
xtro-rotatory; for the transition-tint, $[\alpha] = 94{\cdot}1°$ for $C^{12}H^{11}O^{11}$.
in *water*, and is precipitated by an *ammoniacal solution of neutral*
nearly insoluble in cold, slightly soluble in boiling *alcohol*, quite
bsolute alcohol precipitates it from the aqueous solution.
ses at about 200°. It is carbonised by cold strong *sulphuric acid*,
ith boiling *hydrochloric acid*, and forms oxalic acid with *nitric*
oiling with *dilute sulphuric acid*, it is converted into glucose. In
passes slowly, or sometimes not at all, into vinous fermentation.
00° by aqueous *alkalis*, and scarcely by *potassio-cupric tar-*

PHOR. See COUMARIN (ii. 93).

n. with CADMIUM.

OF. A volatile oil contained in balm (*Melissa officinalis*),
e flowering time, and obtained from it by distillation with water.
-yellow; of specific gravity 0·85 to 0·82; has a peculiar odour;
y. According to Bizio (Brugn. Giorn. xix. 360), it contains a
It dissolves in 5 to 6 pts. of *alcohol* of specific gravity 0·856.
h great rise of temperature and evolution of vapour, and becomes
acid, it turns brown, gives off a large quantity of gas when
esinous. (Zeller, *Stud. über äther. Oele.*, Landau, 1850.)

D. $C^{30}H^{60}O^2 = \left.\begin{matrix} C^{30}H^{59}O \\ H \end{matrix}\right\} O$. — (Brodie, Ann. Ch. Pharm.
cid obtained by treating hydrate of myricyl (melissic alcohol)
bears considerable resemblance to cerotic acid (i. 836), but melts
re, viz. at 88° or 89°. According to Brodie's analysis, it contains
. carbon, and 13·00 to 13·63 hydrogen (calc. 79 64 carbon, 13·27
ygen). The silver salt, $C^{30}H^{59}AgO^2$, is a white precipitate con-
per cent. silver (calc. 19·30).

n. with MELISSIC ALCOHOL, or HYDRATE OF MYRICYL. (See

$^{12}H^{22}O^{11}$.—A kind of sugar obtained from the manna which
rom various species of *Eucalyptus* growing in Tasmania. It was
listinct substance by Johnston (Mem. Chem. Soc. i. 159), more
erthelot (Ann. Ch. Phys. [3] xlvi. 66.—*Chimie organique*,
It is extracted from the manna by water, and crystallises in
ced needles, having a slightly saccharine taste.
elitose are hydrated, containing $C^{12}H^{22}O^{11}.3H^2O$. They give off
nd become anhydrous at 130°. They dissolve in 9 pts. of cold
boiling water, and dissolve also in boiling *alcohol* more freely
alcoholic solution yields small but well-developed crystals. The
s the plane of polarisation to the right: for the transition-tint

th *dilute sulphuric acid* is resolved into a fermentable sugar
ose), and non-fermentable eucalyn (ii. 601):

$$\underset{\text{e.}}{O^{11}} + H^2O = \underset{\text{Glucose.}}{C^6H^{12}O^6} + \underset{\text{Eucalyn.}}{C^6H^{12}O^6}$$

contact with *yeast*, but it is resolved, in the first instance, into
consequently, since the latter is unfermentable, the quantities of
nhydride obtained from it are only half of those which would
ual quantity of glucose. It does not reduce an alkaline *cupric*
tered by boiling with dilute *alkalis* or with *baryta-water*. It is
id, yielding a certain quantity of mucic acid, together with a
lic acid.

CID. Syn. with EUCHROIC ACID (ii. 601).

with MELLONE.

. Syn. with MELLITIC ACID.

Humboldtilite. Somervillite. Zurlite.—A silicate occurring on

Vesuvius and at Capo di Bove, near Rome, in dimetric cryst
cipal is to the secondary axes as 0·6432 : 1. Observed
∞P∞ . P∞ . ∞P2. Angle oP : P∞ = 147° 15′; P∞ : P∞ (ov
P∞ : P∞ (over terminal edge) = 134° 48′. Cleavage ba
= 6. Specific gravity = 2·9 to 3·104. The crystals are brown
lustre, generally translucent, sometimes opaque. Fracture conch
fore the blowpipe it fuses with difficulty to a yellowish or bl
fluxes, the reactions of iron and silica. Gelatinises with acids.

Analyses.—*a. Humboldtilite*, from Somma, by Kobell (Schw
same by Damour (Ann. Ch. Phys. [3] x. 59).—*c, d. Mellili*
by Damour (*loc. cit.*).

	SiO^2	Al^2O^3	Fe^2O^3	FeO	CaO	MgO	Na^2O
a.	43·96	11·20	. .	2·32	31·96	6·10	4·28
b.	40·60	10·88	4·43	. .	31·81	4·54	4·43
c.	39·27	6·42	10·17	. .	32·47	6·44	1·95
d.	38·34	8·61	10·02	. .	32·05	6·71	2·12

These analyses may be approximately represented by the
+ 2(Al^2O^3 ; Fe^2O^3).3SiO^2, which is that of an orthosilicate, th
replaced by magnesium, sodium, and potassium.

Massive Gehlenite, which contains, according to Kobell (
39·80 per cent. silica, 12·80 alumina, 2·57 ferric oxide, 37·64 li
potash, and 2·00 water, may be included in the same general fo

Somervillite, occurring on Vesuvius in dull yellow crystals,
species. (Descloizeaux.)

MELLIMIDE. Syn. with MELLITIMIDE.

MELLITAMIC ACID. See MELLITIC ACID, AMIDES OF

MELLITE, or *Honeystone.*—Native mellitate of aluminium

MELLITIMIDE. See MELLITIC ACID, AMIDES OF.

MELLITIC ACID. $C^{12}H^6O^{12} = \left.\begin{matrix}(C^{12}O^9)^{vi}\\ H^6\end{matrix}\right\}O^6$. *Mellic acid*
steinsäure. (Gm. x. 1.—Gerh. iii. 822.—Bayer, Ann. Ch. P
This acid, which was discovered by Klaproth in 1799, occurs as
in honeystone or mellite, which is the only known source of it.
by Hünefeld (Schw. J., xlix. 215), that it may be produced b
hot hydrochloric acid; but it has not been confirmed.

To prepare it, powdered honeystone is treated with solution
nium, the liquid is boiled till the excess of the ammonium-s
ammonia is added to precipitate any alumina that may have be
is filtered and evaporated till neutral mellitate of ammonium cr
salt is purified by recrystallisation from water, a small quan
each time added, to reconvert the acid salt produced by evapor
into the crystallisable neutral salt. The purified ammoniacal
in water; the solution precipitated with acetate of lead or nitrat
precipitate decomposed by sulphydric acid if it contains lead, or
if it contains silver; and the liquid filtered and evaporated,
hydrochloric acid is expelled. (Wöhler, Ann. Ch. Pharm. xx

The lead-precipitate contains ammonia, which is transferred
Either, therefore, the acid must be re-precipitated with acetate o
which still contains a small quantity of ammonia, washed and
sulphydric acid; and the acid thus liberated precipitated a third
acid, in order to obtain a precipitate free from ammonia, and then
acid by sulphydric acid;—or the ammonium-salt must be boiled
water; the resulting barium-salt decomposed by digestion with
the liquid filtered and evaporated till it crystallises; and th
adhering sulphuric acid by recrystallisation. (Erdmann and

To prepare colourless mellitic acid from the brown acid mother
preparation of mellitate of ammonium, the colouring matter m
chloride of barium; the mellitate of barium thrown down fr
monia, or by boiling with acetate of ammonium, and converted in
nium by digestion with carbonate of ammonium;—or the brown
precipitated by a strong solution of sulphate of copper, and the
of copper decomposed by sulphydrate of ammonium.—In prec
ammonium-salt by nitrate of silver, it is necessary to drop th
cess of the latter; otherwise the precipitate will retain ammonia

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obtained by evaporation, is a white powder exhibiting scarcely crystalline structure; as crystallised from solution in cold alcoevaporation, it forms delicate, silky needles, united in stellate s readily in *water* and in *alcohol*. It is fusible by heat, tastes strongly nent in the air. (Wöhler.)

acid does not give off water at 100°, but at a higher temperature it ltered: the greater portion is however decomposed, with separation rding to Erdmann (J. pr. Chem. lii. 432), the sublimate obtained acid consists of pyromellitic acid, $C^{10}H^2O^8$, which melts in the and solidifies in a radiated crystalline mass. Mellitic acid, when burns with a bright sooty flame, leaving a large quantity of charrds burns completely away. It is not decomposed by boiling *nitric* out the latter dissolves it.

Mellitic acid, formerly regarded as a dibasic acid ($C^4H^2O^4$), has reby Bayer to be sexbasic. The mellitates are decomposed by heat, uantity of charcoal, and a small quantity of products containing slowly distilled with sulphuric acid, they yield pyromellitic acid, onic oxide, carbonic anhydride, and, towards the end, sulphurous

f ammonium, potassium, and sodium dissolve readily in water. The se-salts dissolve more readily in cold than in hot water. The rest aringly soluble in water.

Aluminium, $Al^2O^3.C^{12}O^9.18H^2O = C^{12}(Al^2)^{vi}O^{12}.18H^2O$. — This ative as *mellite* or *honeystone*, in lignite, at Asten in Thuringia, near and near Walchau in Moravia, both crystallised and in massive stals are dimetric, exhibiting the combination P . ∞P . oP . P, &c., predominating. Length of principal axis = 0·7453. Angle P : P '; P : ∞P (lateral) = 93° 22′; P : ∞P = 120° 58′. Cleavage im- P. Hardness = 2 to 2·5. Specific gravity 1·55 to 1·642. Lustre to vitreous. Colour honey-yellow, sometimes reddish or brownish; eak white. Transparent to translucent, and with strong double ire conchoïdal. Sectile.

ntain 14·5 per cent. alumina and 44·1 per cent. water of crystalliiven off at a temperature near the boiling-point of sulphuric acid. compose them, setting the alumina free. They are dissolved by arate from the solution without change of form or constitution.

ne contains a small quantity of a yellow resin, to which it owes its ly also its odour.

assium, added to a solution of alum, forms a crystalline precipitate cent. alumina and 48·0 per cent. water; probably an acid salt.

Ammonium.—The *neutral salt*, $C^{12}(NH^4)^6O^{12}.9H^2O$, forms large t crystals, having a slight acid reaction. They exhibit two forms, erent amounts of water, both belonging to the trimetric system, but bly in the angles.

re derived from an octahedron whose axes are to one another as : 1. Observed combination oP. ∞ P. ∞P̆∞ . P̆∞ . P̆ ∞. Angle oP : P̆ ∞ = 160° 24′; ∞P : ∞P = 144° 16′; ∞P : ∞P̆∞ = 122° 5′. re longitudinally striated. No cleavage parallel to oP.

re derived from an octahedron whose axes are to one another as : 1. Observed combination oP . P . ∞P . ∞P̆∞. Angle oP : P = 146° 17′; P : ∞P = 125° 16′; ∞P : ∞P = 119° 41′; ∞P : Cleavage parallel to oP.

e off 24·1 per cent. water (1 at.) at 100°, and at 150° decomposition volution of large quantities of ammonia and water, and formation of chroate of ammonium:

$C^{12}(NH^4)^6O^{12}$ = $C^{12}H^9N^3O^6$ + $3NH^3$ + $6H^2O$.
Mellitate of ammonium. Paramide.

$NH^4)^6O^{12}$ = $C^{12}H^2(NH^4)^2N^2O^8$ + $2NH^3$ + $4H^2O$.
of ammonium. Euchroate of ammonium.

$^2H^4(NH^4)^2O^{12}.4H^2O$, is obtained by decomposing ammonio-cupric ydric acid. It crystallises in trimetric prisms, having their lateral Observed combination oP . ∞P . ∞P∞ . ∞P̆∞. Angle ∞P :

arium, $C^{12}(Ba'')^3O^{12}.3H^2O$, obtained by double decomposition, is a cipitate, which after a while crystallises in scales, or, if the solutions

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from which it was formed were very dilute, in needles. Mellitic a
of barium forms, after a few seconds, a precipitate compos
crystals.

Mellitate of Calcium is obtained on mixing mellitate of am
of calcium, as an amorphous precipitate, which soon becomes
acid added to lime-water throws down white flocks soluble in hyd

Mellitate of Cobalt, $C^{12}(Co'')^3O^{12}.18H^2O$, crystallises fro
water in microscopic prisms.

Mellitates of Copper.—The *neutral salt*, $C^{12}(Cu'')^3O^{12}.12H^2$
amorphous precipitate, becoming crystalline after a while, on mi
of mellitic acid and cupric acetate. On mixing cold solutions
cupric acetate, there is deposited an *acid salt*, $C^{12}H^2(Cu'')^3O^{12}$
becomes crystalline. On adding a solution of cupric sulphate to
ammonium, a crystalline precipitate is formed consisting of *amm*
$C^{12}(NH^4)^2(Cu'')^3O^{12}.12H^2O$.

Mellitates of Iron.—The *ferric salt* is a cream-coloured p
hydrochloric acid.—*Ferrous salts.* Mellitate of ammonium forms
a greenish-white precipitate, which redissolves when the liquid
raising the temperature to the boiling point, a basic salt, $3Fe''O.$
precipitated in microscopic cubo-octahedrons of a lemon-yellow co
soluble in water, easily soluble in hydrochloric acid; assuming
when dry; and giving off all their water of crystallisation at 19

Mellitate of Lead. $C^{12}(Pb'')^3O^{12}$ (at 180°).—Bulky white p
nitric acid; obtained by adding the acid or the ammonium-salt
of lead.

Mellitate of Magnesium. $C^{12}(Mg'')^3O^{12}.18H^2O$.—Precipi
bonate of magnesium to a hot aqueous solution of mellitic acid, as
to a crystalline mass on cooling.

Mellitate of Manganese. $C^{12}(Mn'')^3O^{12}.18H^2O$.—Obtain
White powder, composed of microscopic needles; more soluble i
water, which dissolves only $\frac{1}{800}$ of it.

Mellitates of Mercury.—The *mercuric salt*, $C^{12}(Hg'')^3O^{1}$
obtained as a white granular mass by triturating mercuric oxi
and a small quantity of water, or by precipitating an alkaline me
nitrate.

The *mercurous salt*, $C^{12}(Hg^2)^3O^{12}.6H^2O$ (at 100°), is also obtai
as a white granular precipitate, very soluble in nitric acid, becomi

Mellitate of Nickel, $C^{12}(Ni'')^3O^{12}.24H^2O$.—When a hot sol
is saturated with carbonate of nickel, a green semi-fluid mass sepe
and becomes vitreous in contact with the air. This salt is ver
water, very freely in dilute hydrochloric and nitric acids. It gi
(4 at.) at 100°, and the rest at 300°.

Mellitates of Palladium.—Mellitic acid is perfectly neu
palladium; but the liquid does not yield any crystals, even whe
syrup; but on evaporation to dryness, it leaves a brown amorphous
mellitate. This salt dissolves in ammonia, forming a colourless li
poration, deposits colourless rhombic crystals, often macled in
containing $12NH^3.C^{12}(Pd'')^3O^{12}.6H^2O$. The whole of the water
together with a small quantity of ammonia. (Karmrodt, Ann. Ch

Mellitate of Palladium and Potassium crystallises from the mix
evaporated to a syrup, in nodular groups of indistinct prisms.
and sodium crystallises in macled triangular pyramids containin
dium. (Karmrodt.)

Mellitates of Potassium.—The *neutral salt*, $C^{12}K^6O^{12}.9H^2$
trimetric crystals, isomorphous with the neutral ammonium-salt
nation oP . ∞P . ∞P∞ . P∞ . P∞. Angle ∞P : ∞P = 114°;
oP : P∞ = 160°; ∞P : ∞P∞ = 123° nearly.

Acid salt, $C^{12}H^2K^2O^{12}.6H^2O$.—A hot solution of 1 at. of the n
mellitic acid yields this salt on cooling in large transparent right
often truncated on the lateral and terminal edges. It is more s
the neutral salt.

A compound of *acid mellitate and nitrate of potassium*, $4C^{12}H^2$
is formed by treating the preceding salt with nitric acid, or by mi
solution of neutral potassic mellitate with nitric acid, as long

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ng the liquid till the precipitate disappears. The double salt then -sided trimetric prisms with dihedral summits, exhibiting the combi- ∞ . $\breve{P}\infty$. It has an acid taste, and is but slightly soluble in water. ellitate of potassium (perhaps $C^{12}H^3K^3O^{12}.C^{12}K^6O^{12}.18H^2O$) is men- ann and Marchand (J. pr. Chem. xliii. 129) as having been ob- n of a crystalline powder on adding mellitic acid to a concentrated utral salt. This powder redissolved in water yielded large nacreou g 20·63 per cent. carbon, 2·74 hydrogen, and 30·49 potash.

Silver.—The *argentic salt*, $C^{12}Ag^6O^{12}$, is obtained on adding mellitic of ammonium to nitrate or acetate of silver, as a white, crystalline, der, which the microscope shows to consist of transparent, colourless, ually having their angles truncated. When heated, it deflagrates iout exhibiting any electric excitement, as the oxalate does under nces. Heated to 100° in a stream of hydrogen, it blackens and gives e residue dissolves in water, forming a dark-brown, strongly acid dually deposits a mirror of metallic silver, leaving a solution of in mellitic acid. The brown or black residue obtained by heating evidently contains *argentous mellitate*. When argentic mellitate to 280° is heated with iodine, iodide of silver is formed, together talline sublimate, strongly acid, and very soluble in water.

Mellitate, $C^{12}K^3Ag^3O^{12}$, is deposited from a mixture of the com- ining nitric acid, in small, transparent rhombic prisms, in which the 21° 30′; $\infty P : \infty\breve{P}\infty = 119° 11'$.

when heated, first give off water and become opaque, then swell up plosion, and leave a residue of silver and potassic carbonate.

Sodium, $C^{12}Na^6O^{12}$, crystallises with two different proportions of centrated solution deposits needles containing 32·81 per cent. (12 at.) of which is given off at 180°. A solution saturated in the cold neous evaporation, large striated triclinic crystals containing 38·88 water, which they give off at 160°. (Erdmann and Marchand.)

Strontium.—White precipitate, soluble in hydrochloric acid, g mellitic acid to strontia-water.

acids derived from mellitic acid, see SUPPLEMENT, pp. 809–814.

ACID, AMIDES OF. (Wöhler, Ann. Ch. Pharm. xxxvii. rz, *ibid.* lxvi. 52.)—Two of these compounds are obtained by the ellitate of ammonium, viz. mellitimide or paramide, which has f triammonic mellitate minus 2 at. water:

$$\underset{\text{Acid mellitate of ammonium.}}{C^{12}H^3(NH^4)^3O^{12}} - 6H^2O = \underset{\text{Mellitimide.}}{C^{12}H^3N^3O^6}$$

cid, which is a mellitamic acid, derived from diammonic mellitate of straction of 4 at. water:

$$\underset{\text{Diammonic mellitate.}}{C^{12}H^4(NH^4)^2O^{12}} - 4H^2O = \underset{\text{Euchroïc acid.}}{C^{12}H^4N^2O^8}$$

e $(C^{12}O^6)^{vi}.H^{12}.N^6$ and mellitamic acid $\left.\begin{matrix}(C^{12}O^6)^{vi}\\ H^6\\ H^3\end{matrix}\right\}N^3O^3$ are obtained,

pricht and Scheibler, by the action of ammonia on neutral mellitate

euchroïc acid are obtained by heating neutral mellitate of ammonium long as ammonia continues to escape, and exhausting the residue with e then remains undissolved, and the solution contains euchroate of

id has already been described (ii. 601).

r Mellitimide, $\left.\begin{matrix}(C^{12}O^6)^{vi}\\ H^3\end{matrix}\right\}N^3$, is a white amorphous powder, insoluble cohol, but soluble in sulphuric acid, whence it is precipitated by water. h water to 200° in a sealed tube, or boiled for some time with water, ammonia, it is converted into acid mellitate of ammonium. By the restricted to a shorter time, it is transformed into euchroïc acid:

$$\underset{\text{Paramide.}}{C^{12}H^3N^3O^6} + 2H^2O = \underset{\text{Euchroïc acid.}}{C^{12}H^4N^2O^8} + NH^3.$$

al solution of paramide, mixed with nitrate of silver, forms a pitate, whose composition (at 150°) agrees best with the formula

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$C^{12}H^{12}Ag^2(NH^4Ag)^2N^6$: at 200° it gives off ammonia, and the silver, corresponding nearly with the formula of argento-pa

Paramic acid.—This name is given by Schwarz to a whi obtained by dropping an ammoniacal solution of paramide in is sparingly soluble in boiling water, and gives with zinc the Its ammoniacal solution is converted by boiling into mellitate found in it (at 179°) 47·25 per cent. carbon, 2·16 hydrogen, and which may be approximately represented by the formula C^{12}

MELLITIC ANHYDRIDE. $C^{12}O^6.O^2$.—This is pro the white substance, insoluble in water and in alkalis, produc mellityl with mellitic acid, and treating the product with wat

MELLITIC ETHERS. *Ethyl-mellitic acid*, $C^{12}H^3(C$ boiling mellitic acid for a considerable time with alcohol saturating with baryta-water, leaving the liquid to stand for s excess of baryta may be precipitated as carbonate, then filte mellitate, and carbonate of barium, a solution of ethyl-mellita which, when evaporated in a vacuum over sulphuric acid, leaves gummy mass, very soluble in water, and rotating on the surfa of barium. It is partly decomposed by drying at 100°. It cipitate other metallic salts. (Erdmann and Marchand,

Neutral Mellitate of Ethyl, $C^2(C^2H^5)^6O^{12}$, is obtained, accor Scheibler (*Limpricht's Lehrb. d. org. Chemie*, p. 1095), as action of iodide of ethyl on mellitate of silver. Kraut (Jah same reaction, obtained the *neutral mellitates of methyl, ethyl*, crystallised. H. Müller (*Kekulé's Lehrb. d. org. Chem.* p. of mellitic acid by the action of chloride of mellityl on the The methylic ether thus obtained was crystallised; the ethyli

According to Limpricht and Scheibler, mellitate of eth ammonia immediately produces a crystalline precipitat $(C^{12}O^6)^{vi}H^{12}.N^6$, and the solution, when evaporated, yields

monium, $(C^{12}O^6)^{vi}\left\{\begin{matrix}H^6\\3NH^4\end{matrix}\right\}N^3O^3$.

MELLITYL, CHLORIDE OF. $(C^{12}O^6)^{vi}.Cl^6$.—Obtai chloric acid and oxychloride of phosphorus, by heating melliti of phosphorus. It is a crystalline non-volatile solid, which acid; with *alcohols*, mellitic ethers; and with *mellitic acid*, Müller, *loc. cit.*)

MELLONE. (Liebig, Ann. Ch. Pharm. x. 4; xxx. 14 227; lxi. 262.—L. Gmelin, *ibid.* xv. 252.—Völckel, lxi. 375.—Gerhardt, Compt. Chim. 1845, p. 24, and i. 473.—Laurent and Gerhardt, Ann. Ch. Phys. [3] produced by the action of heat on various cyanogen-compou cyanogen, melamine, melam, ammeline, ammelide, and chl represents it by the formula C^9N^4 or C^6N^3; but according to t and of Laurent and Gerhardt, the substance thus prod (at least 1·5 per cent.), and may be represented by the form being replaceable by metals. Gerhardt designated this hydra *crude mellone*) by the name hydromellone or hydrome the term mellone for the non-hydrogenous compound, wh is produced by heating mellonide of mercury.

Mellone or hydromellone, heated with potassium or with phocyanate of potassium, yields mellonide of potassium, regarded as a compound of potassium with mellone, C^9N^4K o Gerhardt, on the other hand, assigning to hydromellone the fo that mellonide of potassium is produced by the substitution o the compound $C^9N^9HK^2$. Liebig, by later experiments (An has come to the conclusion that his original formula of mell incorrect, and that the true formula of the neutral mellonide i

Preparation of Hydromellone or Crude Mellone.—Liebig chiefly by heating dried pseudosulphocyanogen to low redness mixture of sulphocyanate of potassium and dry chloride of chlorine gas, and dissolving out the chlorides of potassium residue by water. According to Henneberg, it is best to hea cyanogen, first in an open porcelain basin, and afterwards crucible; because, if it be heated in a retort, the sulphur whic

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mellone to cake together. Too much heat must also be avoided, akes together in hard lumps. The product thus obtained has a th a tinge of grey; a grey or red-brown product may be regarded complete expulsion of the sulphur from the preceding compounds ion, and a large portion of the mellone is thereby decomposed, t prefer preparing it by heating chlorocyanamide till it ceases to acid and sal-ammoniac; or ammeline, as long as it gives off or ammelide, as long as ammonia, cyanic, and cyanuric acids are

ied by either of these processes is a loose, light-yellow, strongly itute of taste and smell. The following table exhibits its com- d by calculation and by analysis.

Formulæ and calculations, according to:

		Laurent and Gerhardt.		
big.				
6 . .	39·13	C^6 . .	72 . .	35·82
6 . .	60·87	N^9 . .	126 . .	62·69
		H^3 . .	3 . .	1·49
2	100·00	$C^6N^9H^3$	201	100·00

Analyses by Laurent and Gerhardt.

	a.	*b.*	*c.*	*d.*
.	35·73 . .	35·8 . .	36·4 . .	36·0
.	62·50 . .	62·4 . .	61·9 . .	62·2
.	1·77 . .	1·8 . .	1·7 . .	1·8
	100·00	100·0	100·0	100·0

Analyses by Völckel.

	g.	*h.*	*i.*	*k.*	*l.*	*m.*	*n.*
1	37·02	32·17	36·52	36·31	35·57	32·49	35·07
.	. .	. .	. .	61·92	62·85		
5	1·91	2·03	1·71	1·77	1·58	1·89	2·09
				100·00	100·00		

rmula on the combustion of crude mellone obtained from pseudo- oxide of copper, which yielded 3 vol. carbonic anhydride to 2 vol. lecomposition of mellone by simple ignition, whereby he obtained 3 vol. cyanogen. Laurent and Gerhardt ignited their mellone tinum crucible before analysing it: *a* was prepared from pseudo- m ammeline, *c* from ammelide, and *d* from chlorocyanamide. *g*, analysed by Völckel, was obtained by variously long ignition gen prepared with nitric acid; *h*, with sulphocyanate of potassium d *k*, from persulphocyanic acid; *l*, from Völckel's *poliene* (i.e. from y heating sulphocyanate of ammonium); *m* and *n*, from sulpho-

preceding analyses, that crude mellone, if the decomposition is oint, has a composition represented by the formula $C^6N^9H^3$, which amide, $\left.\begin{matrix}(C^3N^3)'''\\(C^3N^3)'''\\H^3\end{matrix}\right\}N^3$. The product when further heated still becomes continually richer in carbon. Whether it is possible, to expel the whole of the hydrogen in the form of ammonia, and

having the composition of tricyanuramide $(C^3N^3)^3N^3$ (which ormula, C^3N^4, tripled,) is not yet distinctly made out; but it is the case: at all events, the following formulæ show that melamine y loss of ammonia, be successively converted into melam, dicyan- f hydrogen (according to Liebig's new formula), and ultimately

$2C^3N^4H^4 - NH^3 = C^6N^{11}H^9$.
Cyanuramide. Melam.

$C^6N^{11}H^9 - 2NH^3 = C^6N^9H^3$.
Melam. Dicyanuramide.

$3C^6N^9H^3 - NH^3 = 2C^9N^{13}H^3$.
Dicyanur- amide. Mellonide of hydrogen.

$C^9N^{13}H^3 - NH^3 = C^9N^{12}$.
Mellonide of hydrogen. Tricyanur- amide.

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According to Liebig, pure mellone or tricyanuramide may ing mellonide of mercury till the evolved mixture of cyanog three-fourths absorbed by potash.

Decompositions.—1. Mellone heated in a closed vessel is gr solved into a mixture of 1 vol. nitrogen gas and 3 vol. cyanog

$$C^6N^4 = 3CN + N.$$

According to Völckel, it is resolved hereby into nitrogen, c acid:

$$C^6N^6H^3 = 3CNH + 3CN + N^3$$

When mellone obtained from ammelide or chlorocyanamic disappears completely, giving off vapours which smell of ar acid, and deposit first a red, then a yellow, and lastly a re sublimate gives off ammonia when treated with potash, and pr The gaseous mixture evolved at the same time contains a ga sorbed by hydrochloric acid, another (cyanogen) which is al non-absorbable gas (nitrogen), the relative quantities of the ning of the experiment = 9 : 51 : 40, and at the end = 10 : 8 Gerhardt.)

2. Mellone heated in dry *chlorine gas* forms a white vol powerful odour, and attacking the eyes very strongly.—3. M in boiling *nitric acid*, continually giving off a gas which cont oxide, and is resolved into ammonia and cyanylic acid (ii. 2 long needles:

$$C^6N^4 + 3H^2O = C^6N^3H^3O^3 + NH^3. (1$$

Or,

$$C^6N^6H^3 + 6H^2O = 2C^3N^3H^3O^3 + 3NH^3. \text{ (Laurent}$$

4. Mellone dissolves in strong *sulphuric acid*, with evolution to the solution throws down a white substance different from

5. Crude mellone heated with *potassium*, or with *iodide, of potassium*, is converted into mellonide of potassium.

6. With a cold solution of *caustic potash*, it forms melloni the boiling heat is converted, with evolution of ammonia an into cyamelurate of potassium (ii. 187):

$$\underset{\text{Mellonide of potassium.}}{2C^6N^{12}K^3} + 9H^2O = 3NH^3 + \underset{\text{Ammelide.}}{C^6N^3H^3O^3} + \underset{\text{Cyame pota}}{2C^{}}$$

MELLONHYDRIC ACID. See the next article.

MELLONIDES. $C^6N^9M^3$, according to Gerhardt; C^6N latest experiments (Ann. Ch. Pharm. xcv. 257). Mellonide as already observed, by the action of potassium, or of iodide, of potassium, on crude mellone. This and the corresponding monium are soluble in water; the other mellonides are insol and are obtained by precipitation. The sodium- and ammon decomposing mellonide of barium with carbonate of sodium o

Mellonide of Ammonium crystallises in needles lik contains water of crystallisation.

Mellonide of Barium is obtained by treating the solu with chloride of barium, as a white precipitate which dissolv boiling water. The saturated solution deposits the salt i needles containing 20·87 per cent. water of crystallisatio 120°.

Mellonide of Calcium, obtained in like manner, is mor than the barium-salt. The crystals contain 18·05 per cent. at 120°.

The following are obtained as precipitates: *mellonide of ca* bluish-white; *cobalt*, peach-blossom-coloured; *copper*, parro yellow.

Mellonide of Hydrogen. Mellonhydric or *Hydromel* mixing a warm solution of mercuric chloride with mellonide of dazzling white precipitate of mellonide of mercury is obtain dissolves in dilute hydrocyanic acid, even in the cold. Sulph this solution throws down all the mercury in the form of sulp the hydrocyanic acid by a gentle heat, there remains an aque lonic acid, which has a strong acid taste and reaction, mix

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rbonic acid from carbonates with effervescence, and yields, when ash, crystallised mellonide of potassium, exhibiting all the properties Liebig). L. Gmelin prepared the acid by decomposing the lead sulphydric acid.

of hydromellonic acid is evaporated, in vacuo or in the air, either gher temperatures, it deposits white films or flakes, and leaves a e residue, which redissolves but partially in cold water. The acid is etely decomposed under these circumstances; but the portion soluble a certain quantity of mellonide of potassium when saturated with ith alcohol. (Liebig.)

Iron.—The *ferric salt* is a dark-yellow precipitate; the *ferrous* ate with greenish reflex.

ead is a white precipitate which, after drying in the air, gives off r when heated in a bath of chloride of calcium. The air-dried salt . Gmelin's analysis, 42·45 per cent. lead, agreeing nearly with the $5H^2O$, which requires 42·58 per cent.

Magnesium is deposited, after some time, in small interlaced ure of mellonide of potassium and sulphate of magnesium.

Manganese is a white precipitate.

Mercury.—The *mercuric salt* is a white precipitate deposited on ng mixture of the solutions of mellonide of potassium and mercuric tions are mixed cold, the precipitate contains potassium. The salt es off nitrogen, cyanogen, and hydrocyanic acid; then nitrogen and portion of 1 vol. of the former to 3 vol. of the latter. (Liebig.)

lt, also obtained by precipitation, forms thick white flocks.

Platinum is a brownish-yellow precipitate.

Potassium.—Three of these salts have been obtained, viz the ^{3}, and the two acid salts, $C^9N^{13}HK^2$ and $C^9N^{13}H^2K$.

ide of potassium is obtained in many reactions besides those above viz. by the action of amidated compounds of cyanogen on potas- action of sulphocyanates on potassium-salts; and by the decom- yanate of potassium under particular circumstances. When, for lone (or calcined melam, &c.) is added to fused sulphocyanate of le of potassium is produced, with evolution of sulphide of carbon, ellone, but also from the elements of the sulphocyanate. Again, of copper is added to melting sulphocyanate of potassium, sulphide , and mellonide of potassium remains mixed with metallic sulphide. ssium is also formed by heating sulphur with ferrocyanide of n the mixture used for preparing sulphocyanate of potassium is too formation being due to the mutual action of the sulphocyanates of formed in the first instance. All these modes of formation of ium from sulphocyanates become intelligible on observing that a ins the elements of sulphide of carbon, a metallic sulphide, and a

$$\underset{\text{Sulphocyanate.}}{13CNSM} = \underset{\text{Mellonide.}}{C^9N^{13}M^3} + 5M^2S + 4CS^2.$$

lellonide of Potassium.—*a.* From the *Sulphocyanate.* The prepara- y facilitated by the presence of a metal capable of taking up a hur which is set free as sulphide of carbon. The following pro- nded by Liebig (Ann. Ch. Pharm. xcv. 257):

nious chloride (*butter of antimony*).—7 pts. of sulphocyanate of l in a wide and deep porcelain crucible till the whole runs quietly g, and 3 pts. of recently-prepared butter of antimony then added Strong intumescence then takes place, accompanied by brisk le of carbon, which breaks out in flames, and must be extinguished rucible with a shallow dish; and a red-brown, porous mass is ust be pulverised and heated, with constant stirring, in an iron f the resulting sulphide of antimony melts in the softened pulp t the bottom. The mass is then immediately dissolved in boiling boiled with hydrated oxide of lead as long as the oxide turns black, of potassium and dissolved sulphide of antimony; and the liquid eft to cool, whereupon it generally solidifies to a crystalline magma onide of potassium. This product is thrown on a filter, the liquid off, and the mass, without being washed, is wrapped up with the per, and placed over-night between two bricks, which are gradually

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loaded with weights. The mass, when dry, is again di
the same process repeated. At the third crystallisation, the
with a small quantity of alcohol, till a faint transient turbi
The crystalline magma which settles down is washed with
liquor has drained off, till a drop of the liquid which
sesquichloride of iron, and therefore no longer contains sulp
2. The chloride of antimony used in this process may,
replaced by *chloride of bismuth*. This compound is prepar
over commercial bismuth, heated in a tube of hard glass, wh
wards at one end, then again downwards, and lies horizontal
the chloride of bismuth, which distils over, is purified
metals by rectification in the same apparatus. Before bein
pulverised while still hot after solidification, and the p
sulphocyanide. The proportions used are 1 pt. of bismuth
cyanate of potassium; with a larger proportion of the for

b. From *Melam*.—8 pts. of sulphocyanate of potassium
melam, previously slightly ignited, and added in succes
temperature must not be allowed to rise too high; if the g
the melted mass do not burn with a blue flame (sulphide o
colour, indicating the formation of cyanogen, the heat must

Pure mellonide of potassium forms soft, white, very
having a silky lustre, and scarcely distinguishable in ap
quinine.—1 pt. of the salt dissolves in 37·4 pts. of water at
in a much smaller quantity of hot water: it is insoluble i
difficulty, even from a solution saturated while warm, but
alcohol. Its solubility in cold water is greatly diminish
salts. A warm saturated solution, which would stand for
crystallising, instantly deposits crystals on addition of
sulphocyanate of potassium.—The aqueous solution taste
quinine. In doses of a drachm, the salt exhibits no deci
animals, none at least which would distinguish it from ot
crystals heated to 200° give off 18·06 per cent. (5 at.) wat
The composition of the anhydrous and crystallised salts,
given in the following table:—

	Anhydrous.		Liebig.	*Cry*
C^6 . .	108·0	26·50 . .	26·12	$C^6N^{12}K^2$
N^{12} . .	182·0	44·65 . .	44·38	$5H^2O$.
K^2 . .	117·6	28·85 . .	28·72	$C^6N^{12}K^2.5H^2$
	407·6	100·00	99·22	

The dried salt burnt in a stream of oxygen yielded only 0
it contained 1 at. hydrogen to 2 at. potassium, accordi
$C^6N^9HK^2$, it should have yielded 2·19 per cent. water; it
that the salt does not contain hydrogen.

Neutral mellonide of potassium, boiled with hydrochlori
chloride of potassium, and cyanuric acid. Boiled with ni
acid. By continued boiling with potash, it gives off amm
melide and cyameluric acid, then melanuric acid, and finall

β. *Soluble Acid salt*. $C^6N^{12}HK^2.3H^2O$.—Obtained by
solution of the neutral salt with an equal volume of strong
from this mixture in oblique rhombic laminæ, which efflore
When boiled with water, it is resolved into the neutral
acid salt *b*. The crystals, after drying in the air, give off
= 12·73 per cent.). The salt, dried at 150°, gave b
carbon, 0·43 hydrogen, and 21·13 potassium; the formula
carbon, 49·28 nitrogen, 0·27 hydrogen, and 21·22 potassium.

γ. *Insoluble Acid salt*. $C^6N^{12}H^2K$.—This salt separates in
precipitate, on pouring a moderately dilute solution of neut
into warm dilute hydrochloric acid. It is insoluble in cold and
water; the solution has a strong acid reaction; easily solub
of potassium. It gave by analysis 31·97 per cent. carbon,
potassium; the formula requiring 32·61 per cent. carbon, 54
and 11·84 potassium.

Mellonide of Silver, $C^6N^{12}Ag^2$, is obtained as a wh
boiling solution of neutral mellonide of potassium with nit
according to the mean of Liebig's analyses, 17·48 per c

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50), the formula requiring 17·59 carbon, 29·64 nitrogen, and 52·77

dt found in this salt 17·01 to 17·8 per cent. carbon, 52·2 silver, ogen; whence they deduced the formula $C^6N^3HAg^2$, requiring 0·2 H. Liebig, however, by burning the salt in a stream of o experiments only 0·4 and 0·3 per cent. water; whereas, according the quantity of water should be 2·17 per cent., or about six actually obtained. Hence it may be inferred that the salt does

dium, obtained by decomposing the barium-salt with carbonate in white silky needles, moderately soluble in water, insoluble

rontium is more soluble in water than mellonide of barium; at the boiling heat, solidifies, on cooling, to a magma composed

nc is a white precipitate.

N. An emetic principle contained, according to Torosiewicz, in (*Cucumis Melo*). See CUCUMIS (ii. 172).

A yellowish- or greenish-white lithomarge from Neudeck in = 2 to 3. Specific gravity = 2·5 to 2·6. (Breithaupt.)

E. Titaniferous iron. (See TITANATES).

MIDE. **AMINE.** } See NAPHTHYLAMINE, DERIVATIVES OF.

An oxychloride of lead, $Pb^3Cl^2O^2$, found on the Mendip Hills in .

. A sulphide of lead and antimony, $4PbS.Sb^2S^3$, occurring, Jamesonite, at Bottino in Tuscany, generally in compact fibrous in distinct trimetric crystals, exhibiting the faces $\infty\breve{P}\infty$ and el to $\infty\breve{P}\infty$ and oP (Q. Sella, Jahresb 1862, p. 712). Hardness . Contains, according to Bechi's analysis (Sill. Am. J. [2] xiv. ulphur, 19·28 antimony, 59·21 lead, 3·54 copper, and 0·34 iron

mineral containing zirconia, ferric oxide, and titanic acid, occur- in the Ilmen Mountains. It forms short trimetric prisms, often ded pyramids. $a : b : c = 0{\cdot}8285 : 1 : 0{\cdot}8669$. Angle $\infty P : \infty P = 133° 42'$. No distinct cleavage. Hardness = 5 to 5·5. Specific crystals are iron-black, with submetallic lustre, subvitreous on . Streak chestnut-brown. Fracture uneven. Infusible before omes magnetic. Greenish-yellow clear glass with phosphorus- ; yellowish-red in the inner, deepened by adding tin. Manga- bonate of sodium.

ed ilmenite by Brooke; and the name mengite is applied by nonazite.

brown opaque variety of opal, occurring in compact reniform laty.

C ACID. A doubtful acid, said by Boullay to exist in the *n Cocculus*, and to be obtained by evaporation of the alcoholic hich picrotoxine has crystallised out. It is described as crystal- ly soluble in water, capable of reddening litmus, and forming th alkalis. Neither Casaseca nor Pelletier was able to obtain er described by Boullay.

NE. An alkaloïd discovered by Pelletier and Couerbe iv. 178) in the seeds of *Menispermum Cocculus*, in which it is enispermine and picrotoxine.

ispermine, the alcoholic extract of the seeds is first treated with austed with hot acidulated water; the brown solution is pre- ; and the precipitate is exhausted with very weak acetic acid, black mass undissolved. Or the seeds may be made up into a with alcohol of specific gravity 0·833; the alcohol distilled off; th water; and the liquid filtered at the boiling heat; it then, on tals of picrotoxine, especially if a small quantity of acid has t insoluble in boiling water is then treated with acidulated water, n alkali; a granular precipitate is thereby formed, from which

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alcohol extracts a peculiar yellow substance; and the ether, which deposits menispermine in the crystal undissolved a viscous substance, which may be dissolved solution, evaporated at 45°, ultimately yields crystals of

Menispermine crystallises in prisms terminated by melts at 120°, and decomposes at a higher temperatu poisonous. It is insoluble in *water*, but soluble in *alco* in the crystalline state. It contains (mean of four an 8·01 hydrogen, 8·57 nitrogen, and 10·53 oxygen; whence the formula $C^{18}H^{12}NO^2$.

Menispermine dissolves easily in dilute *acids*. Hot into oxalic acid, and a yellow resinous substance.

Sulphate of menispermine crystallises in prismatic n water and 6·87 per cent. sulphuric anhydride. It me temperature reddens slightly and gives off sulphydric ac

Paramenispermine has the same composition as m and volatilises in white vapours, which condense like s soluble in *water*, sparingly soluble in *ether*, easily s dissolves also in dilute *acids*, but without neutralising t

MENTHENE. $C^{10}H^{18}$. (Walter, Ann. Ch. Pharm Chem. Soc. J. xv. 29.)—A hydrocarbon produced by th dride (Walter), or chloride of zinc (Oppenheim), on m $C^{10}H^{20}O$. It is also found among the products of the menthyl by ethylate of sodium (Oppenheim). To p in a tubulated retort, and phosphoric anhydride is ad is in slight excess. The mass is then distilled, and the lation over fresh portions of phosphoric anhydride.

Menthene is a transparent, very mobile liquid, ha cooling taste. Boiling-point 163°. Specific gravity = obs. = 4·93 to 4·95; calc. = 4·78. It is insoluble in w with a small quantity of *alcohol* or *ether*, a clear mixtur solves with moderate facility in *wood-spirit*, very easily

Menthene is scarcely, if at all, attacked by *potassium* action upon it; *nitric acid* ultimately converts it into and in alcohol; with *chlorine* and *bromine* it forms subst

Bromomenthene. $C^{10}H^{17}Br$.—Bromine acts very viole torrents of hydrobromic acid, and forming a number products. By adding 2 at. bromine drop by drop to 1 at. m appears to be formed, the product treated with pota $C^{10}H^{16}$ (Oppenheim):

$$C^{10}H^{17}Br + KHO = KBr + H^2$$

Pentachloromenthene, $C^{10}H^{13}Cl^5$, is produced by the act Dry chlorine attacks menthene with great violence, hy the liquid assuming first a green, then a yellow colour, a into pentachloromenthene, which is a yellow syrupy li dissolves at ordinary temperatures in *alcohol* and *wood-sp* *oil of turpentine*. Strong *sulphuric acid* colours it deep

MENTHOL. $C^{10}H^{20}O = \left.\begin{matrix}C^{10}H^{19}\\H\end{matrix}\right\}O$. *Menthylic*

Camphor or *Stearoptene of Peppermint-oil*. (L. Gmelin Dumas, Ann. Ch. Pharm. vi. 252.—Blanchet and S *ibid.* xxxii. 288.—Kane, Phil. Mag. xvi. 418.—Laur Oppenheim, Chem. Soc. J. xv. 24). The essential oil o long time, or cooled to very low temperatures, deposi American peppermint-oil yields this deposit at tempera is now imported in large quantities from Japan, in sm crystals, resembling sulphate of magnesium, which salt the Japanese camphor, sometimes to the amount of 10 to

The camphor from American oil of peppermint melts (Dumas); 27° (Blanchet and Sell); 34° (Walter) at 36°, and volatilises without decomposition at 210° (sity, obs. = 5·62; calc. = 5·41. It is lævo-rotatory. [s sition tint.]

It is but slightly soluble in *water*, but imparts to that It is very soluble in *alcohol*, *ether*, *sulphide of carbon*, and insoluble in aqueous *alkalis*. From an alcoholic soda-s

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ed by a current of *sulphurous anhydride*, or *hydrochloric acid gas*, ff on evaporation, leaving the menthol unaltered. Concentrated c, *sulphuric*, *hydrochloric*, *formic*, *acetic*, and *butyric acids*, dissolve hese solutions it is precipitated by water and by alkalis, as an oil, and then exhibits the original properties of the camphor.

hydrochloric to 100° for a considerable time, it is transformed enthyl, $C^{10}H^{19}Cl$. The same compound is formed by the action osphorus:

$$H^{20}O + PCl^5 = PCl^3O + HCl.C^{10}H^{19}Cl.$$

omide of phosphorus, it yields iodide and bromide of menthyl; ts upon it at 200°, forming iodide of menthyl.

ntrated *acetic acid* in a sealed tube, it is converted into acetate $\left.\begin{matrix}C^{10}H^{19}\\C^2H^3O\end{matrix}\right\}O$. With *butyric acid* it forms, in like manner, butyrate of .

ow that peppermint-camphor is an alcohol containing the radicle is homologous with allylic alcohol, C^3H^6O, and isologous with camphol, $C^{10}H^{18}O$ (i.e. differs from the latter by 2 at. H): hence ic or mentholic alcohol, and menthol applied to it.

energetically on menthol, with evolution of hydrogen and for- on-product, which is a white, vitreous, transparent mass, becoming the air, insoluble in water, but soluble in absolute alcohol and latter body acts on the sodium compound; but the action is com- appear to give rise to the formation of a compound ether, as with .

rated by *phosphoric anhydride* or *chloride of zinc*, yielding

$^{10}H^{19}$. The radicle of menthylic alcohol, &c.

l, $\left.\begin{matrix}C^{10}H^{19}\\C^2H^3O\end{matrix}\right\}O$, prepared by heating menthol with strong acetic acid be for ten or twelve hours, then washing with carbonate of sodium, ide of calcium, is a light oil which boils without decomposition °. It is highly refractive, and lævo-rotatory; $[\alpha] = -114°$. It is ater, or by cold solutions of the alkalis, or by baryta, but when an alcoholic solution of soda, it is completely resolved into sodic (Oppenheim, Chem. Soc. J. xv. 26.)

hyl, $\left.\begin{matrix}C^{10}H^{19}\\C^4H^7O\end{matrix}\right\}O$, is prepared by heating menthol with butyric e, to 200° for thirty hours; then distilling and collecting the over between 230° and 240°. Rotatory power $[\alpha] = 88{\cdot}8°$

yl, $C^{10}H^{19}Cl$. Obtained by treating menthol with pentachloride of), or with concentrated hydrochloric acid for a week, at 100°, or at 120° (Oppenheim). It is a very pale yellow liquid, lighter han alcohol, and having an odour like that of mace; boils at ing and turning brown at the same time. It is slightly soluble e in alcohol. It is rapidly decomposed by potassium, but strong o action upon it, even at the boiling heat. (Walter.)

e of Menthyl are obtained by the action of bromide and iodide of ol; the latter also by the action of strong hydriodic acid. Both posed by distillation. (Oppenheim.)

r. $C^{22}H^{36}O^{11}$.—A bitter substance discovered by Brandes in *s trifoliata*), and further examined by Kromayer (Zeitschr. ahresb. 1861, 747). It may be prepared by a process similar to extraction of marrubiïn (p. 854). It is thus obtained as a nearly ass, which, after drying over sulphuric acid, is amorphous, friable, neutral, and has an intense and purely bitter taste. It begins ° and 65°, becomes quite fluid at 115°, and solidifies on cooling transparent mass. At higher temperatures it gives off first nt vapours, smelling like oil of mustard. It dissolves sparingly in hot water and in *alcohol*, but is insoluble in *ether*; *alkalis* y without alteration. It dissolves with various shades of colour , *nitric*, and *hydrochloric acids*. The aqueous solution is not lic *salts*, but form with *gallotannic acid* a precipitate having the

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composition $C^{56}H^{42}O^{22}$ = $C^{42}H^{36}O^{11}.2C^6H^8O^6$. Menyanthi
picrin, which it also resembles in many of its properties. (
The name menyanthin has also been applied to a neut
contained in buckbean; probably identical with inulin (p. 27

MENYANTHOL. An oily body, obtained by distillin
sulphuric acid. The residue in the retort contains ferments
colourless, smells like bitter almond oil; has a faint acid
ammoniacal silver solution. (Kromayer.)

MERCAPTANS. Sulphydrates of the alcohol-radicles,
$C^2H^5\}S$. (See the several Alcohol-radicles, *e.g.*, Ethyl, ii. 54
$H\}$

MERCAPTIDES. Compounds formed by the substituti
in the mercaptans.

MERCURAMINES AND MERCURAMMONIUM
Ammoniacal.

MERCURIALIS. The ash of *Mercurialis perennis* (th
fruit) has been analysed by N. Reitler (Jahresb. 1860,
plants yielded 84·4 per cent. dry residue at 100°. The ash an
of the air-dried plant, and 13·09 per cent. of the plant drie
27·14 per cent. CO^2, 9·18 Cl, 0·98 SO^3, 0·84 SiO^2, 2·74 P^2O
5·59 MgO, 14·35 K^2O, 6·84 Na^2O, with a trace of copper (los

MERCURIC AMYLIDE, ETHIDE, &c. See Mer

MERCURIUS. This term was applied by the alchemists
thus quicksilver was called *Mercurius communis;* alcohol,
present it is applied only to quicksilver.

Mercurius dulcis. Syn. with calomel (p. 893).

Mercurius cinereus Blackii, blackish-grey mercurial
of mercurous carbonate with *Mercurius solubilis Hahnemanni*
mercurous nitrate with carbonate of ammonium.

Mercurius cinereus Moscati, the *Mercurius solubili*
of black mercurous oxide, obtained by decomposing calome
soda.

Mercurius cinereus Saunderi. An almost obsolete
tion consisting of chloride of mercurosammonium (Hg^2H^2N
posing calomel with ammonia. (See Mercury-bases, Ammo

Mercurius phosphatus Fuchsii. An obsolete prep
cipitating a solution of mercury in nitric acid with phosphat

Mercurius præcipitatus albus. Hydrargyrum am
gyrum amido-muriaticum, Hydrargyrum præcipitatum album
hydrargyri alba, Lac mercuriale.—White precipitate. Of th
there are two varieties, distinguished as fusible and infu
sists of *chloride of mercurammonium*, $Hg''H^6N^2Cl^2$, obtained b
mercuric chloride with potash, or by dropping a solution of
solution of sal-ammoniac mixed with ammonia, as long as th
is redissolved; the latter, of *chloride of dimercurammonium*
adding ammonia to mercuric chloride.

Mercurius præcipitatus ruber. Oxydum hydrarg
obtained either by oxidising mercury in contact with the air
heating it with nitric acid. The product obtained by the firs
called *Mercurius præcipitatus per se* (see p. 907).

Mercurius solubilis Hahnemanni. Hydrargyr
Nitrus ammonicus cum oxydo hydrargyrico. Basic nitrate o
Mercury-bases, Ammoniacal.

Mercurius violaceus. A form of mercuric sulphide,
together 6 pts. melted flowers of sulphur, 6 pts. mercury, and 4
ising the cooled mass, subliming it in a flask, removing the up
ing of sal-ammoniac, and resubliming the lower, heavier sub
upper part of the sublimate, thus obtained, is usually light an
and violet. The latter, after it has been finely pounded an
constitutes *Mercurius violaceus.*

Mercurius vitæ. Powder of Algaroth (oxychloride of
Mercurius vivus. Metallic mercury.

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TRETHYL-AMMONIUM. $Hg''(C^2H^{10}N)^2$. A base, the btained, according to Sonnenschein, together with several other tion of iodide of ethyl on *white precipitate* (ii. 535).

nonymes: *Quicksilver*, *Hydrargyrum*, *Argentum vivum*, *Mercurius* Atomic Weight = 200.

n known from the earliest times; cinnabar was used as a pigment rosive sublimate was known to the Arabians, and calomel to the

und native, in globules disseminated through its ores; it occurs lver and with gold, in the form of amalgams; also as iodide and rely as selenide; but the most abundant ore is the sulphide, or nearly all the mercury of commerce is obtained. Its most im- se of Idria in Illyria, and of Almaden in Spain. At Almaden often nearly fifty feet thick, traversing micaceous schists of the l; in Illyria it is disseminated in beds of grit, bituminous schist, of more recent date. It occurs also in the Bavarian Palatinate, emia, at Schemnitz in Hungary, and a few other localities in and Altai mountains; in China abundantly, and in Japan; at co; abundantly at Huanca Velica, in Southern Peru; in the o, Chile; and forms extensive mines at New Almaden in

stilling mercurial ores with lime, smithy-scales, or simply in contact remove the sulphur by formation of sulphide of calcium, sulphide anhydride; partly also to remove chlorine. In the Bavarian Pala- re and lime is heated to redness in long cast-iron bottles, placed ows, one above the other in a long furnace, and provided with vitz, in Bohemia, a mixture of ore and smithy-scales is placed are attached one above the other by the centres of their bases to d covered over with an iron receiver, closed at top, and dipping

The upper part of the receiver is surrounded by the furnace, o the dishes, from which the mercury rises in vapour, and collects l in the trough. This process is called *Destillatio per descensum* the quicksilver-ore, coarsely broken up, is laid upon a perforated -shaped furnace, and after the apertures by which it is introduced ated to redness by flames made to play against the under surface phur is burnt by the air, which is admitted through channels urpose; and the mixture of mercurial vapour, sulphurous acid, rnace, is made to pass through a horizontal channel constructed ie furnace, then up and down through seven condensing chambers, a turret-shaped forge into the air. In the course of this long ondenses in the chambers, the floor of which, being inclined to run out; it is then collected, and strained through coarse cloth. llowed at Almaden, in Spain, excepting that the vapours, instead ndensing chambers, are made to traverse a series of tubes made d *Aludels* (i. 149), open at both ends, and fitting one into the l upon a surface, called the *Aludel-bath*, first descending a little, nd finally open into the chimney. [For details and figures of all atus, and of an improved process suggested by Dr. Ure for tion in iron retorts, see *Ure's Dictionary of Arts*, &c., iii. 58]. the market, sometimes in leathern bags, sometimes in wrought- afterwards used in chemical laboratories for the preparation of

foreign metals.—1. The mercury is distilled either alone, or, yer of iron filings, in glass, earthen, or other retorts. A portion s very apt to pass over with the mercury, either in the form of during the ebullition. The latter of these accidents is prevented n-filings. 2. By distilling the mercury with one-tenth of its sulphur of which retains the foreign metals. (Därfurt.) pure mercury for some hours with $\frac{1}{67}$ of its weight of mercurous ater, or with a small quantity of very dilute nitric acid, or by r of these liquids in the cold, the mercury being placed in a xpose a large surface, and frequently agitated; or by agitating days with sulphuric acid—which must be stronger, as the mer- till the acid no longer becomes turbid, or takes up any foreign Repert. Pharm. vi. 77).—4. Ulex (Ann. Ch. Pharm. lx. 210) f mercury with half an ounce of solution of ferric chloride,

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having a specific gravity of 7·65. The mercury is thereby
fine division, and the action on the foreign metals is acce
chloride of mercury, which collects between the drops.
the mercury with the iron solution for ten minutes, and ther
mercury, after drying, is easily reunited by the application of
quantity of mercury may be speedily purified by placing it in
powdered loaf-sugar, the mercury not occupying more than
of the bottle; the bottle is then closed and briskly agitat
which the stopper is withdrawn, and fresh air blown in
bellows, and the agitation is repeated; this is done thr
mercury is then poured into a cone of smooth writing pap
apex. The metal then runs through, leaving the pound
oxides of the foreign metals, and a considerable quantity of

Pure mercury should leave no residue when dissolved in
ignited; or when fused with sulphur and sublimed in a
run down a gently-inclined surface, it should retain its
tail; and when agitated in a bottle with dry air, it should

Properties.—Mercury freezes, according to Hutchins, at
siderable contraction, and forming a tin-white, ductile mass,
and needles, capable of being cut with a knife, and exhibiti
ordinary temperatures, it forms a very coherent but very mo
but slightly to glass, and has a density of 13·5592 (Kar
13·535 at 26° (Kupffer), 13·568 (Cavendish and Brisso
13·613 at 10° (Biddle), 13·595 at 4° (Kopp), 13·596 (Re
heat see HEAT (p. 30); rate of expansion (pp. 54-57); late

Mercury remains unaltered when agitated for any length
common air, hydrogen, nitrogen, nitrous oxide, nitric ox
alcohol; but any foreign metals that may be mixed wi
agitation in air or oxygen gas, producing a grey pulverulen
the foreign metals and finely divided metallic mercury. O
tion with water, ether, or oil of turpentine, or by triturat
of antimony, sugar, grease, &c., even in vacuo, mercury is co
Æthiops per se, consisting of small globules of the metal,
terposition of foreign matter, but run together again on
the *Extinction* or *Deadening of Mercury*. In well prepare
the mercury forms nearly uniform globules, having a diame
a line, and not distinguishable by the naked eye (Ehrenb
deadening of mercury was formerly attributed to oxidatio
sprung (J. pr. Chem. l. 21), some, at least, of the mercury
is in the state of black oxide (the quantity being greater, th
this oxide, after the fat has been extracted by ether, may
slightly acidulated with sulphuric acid.

Mercury boils, according to Crichton, at 346°; a
349°; according to Heinrich, at 356°; according to Du
and is thereby converted into a colourless vapour. Vap
mercury, even between + 15·5° and 27° (but not at −
in spaces filled with air, as shown by the silvering of gold-
in a vessel over mercury (Faraday, 7°). According to
lxxi. 245), mercury at temperatures below 0°, gives off
out the image on a Daguerreotype plate held over it. Bran
that sulphur in the very finely divided utricular conditio
which it is first precipitated from the state of vapour, is a m
the presence of mercurial vapour than gold-leaf. By mean
at 12° the vapour of mercury rises to a height of more than
it appears to have no limited atmosphere—that it rises, at o
amalgams and mercurial ointment—that in presence of a
diffuses, according to the same law as other gases—but
iodine-vapour, and of the vapour of iodide of mercury the
diffusion appears to be different. (For the tension of m
temperatures, see HEAT, p. 94.)

The density of mercury-vapour, referred to air as unity,
rend. xlix. 799). The theoretical density is 100 referre
referred to air, as unity, the molecule of the vapour contai
1 at. Hlg (= 200).

According to Wiggers (Pogg. Ann. 440), mercury is s
water. When twenty ounces of water are poured upon tw
boiled down to ten ounces, the decanted liquid shows no

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stannous chloride; but on mixing it with ten drops of nitric acid, e residue exhibits a slight brown tint when treated with sulphydric so (J. pr. Chem. xv. 153) found that water boiled with mercury for hen decanted, was capable of silvering gold-leaf; and after evapo- acid, gave the characteristic reactions with sulphydric acid and Paton and Favrot (J. Chim. méd. xiv. 306), in repeating the gers with distilled water and with river-water, did not discover r after evaporation with nitric acid: Girardin also (J. Chim. méd. mercury in water which had been boiled with that metal; he did t with nitric acid before evaporation. When water is poured upon vn to one-half, decanted, then left to stand for several days, again wn upon a thick paper filter, small quantities of mercury, sufficient emain on the filter; but the filtrate, when mixed with nitric acid ows no trace of mercury. Perhaps the quantity used in the ex- small; but, at all events, the experiment shows that the mere d by Wiggers is not sufficient to separate the water from the lly mixed with it; to decide the question completely, experiments h large quantities of water. (L. Gmelin, *Handbook*, vi. 4.)

l, even when hot and concentrated, has no action upon mercury. issolves it in the cold; and, if the acid is in excess, converts it into itrate. When nitric acid is boiled with excess of mercury, the into basic mercurous nitrate, which crystallises on cooling. If, on nitric acid is in excess, the whole of the mercury is converted into ercury heated with excess of *nitromuriatic acid*, yields mercuric e. Mercury is scarcely attacked by dilute *sulphuric acid*, but when ncentrated acid, it is converted into solid mercuric sulphate, with ous anhydride. If the sulphuric acid is small in quantity, and the uite to the boiling point, mercurous sulphate is obtained. *Chlorine* tly heated mercury, converts it into mercuric chloride.

vo series of compounds, viz. the mercuric compounds, into which enters as a bivalent radicle, and the mercurous compounds, in rcury are linked together so as to form a bivalent radicle (Hg – Hg)″;

oride . .	$Hg''Cl^2$	=	200 + 2 . 35·5	=	271
de . . .	$Hg''O$	=	200 + 16	=	216
ıloride . .	$(Hg^2)''Cl^2$	=	2 . 200 + 2 . 35·5	=	471
ide . . .	$(Hg^2)''O$	=	2 . 200 + 16	=	416

veral compounds in which mercury forms part of a base or radicle pes ammonia and ammonium, *e.g.* bromide of mercurammonium ide of tetramercurammonium, $(Hg'')^4N^2Cl^2$. Trimercuramine, in the free state.

LLOYS or **AMALGAMS OF.** Mercury is capable of uniting etals, forming compounds called amalgams, some of which are are solid. The solid amalgams appear to be for the most part of nstitution; while the liquid amalgams may be regarded in many s of definite compounds in excess of mercury, inasmuch as when they hamois leather, mercury containing but a small quantity of the other n, while a solid amalgam, frequently of definite atomic constitution, ven in the solid amalgams, however, the affinity by which the two ther is but feeble; for Joule has shown that many of those which ers of atoms of their component metals may be partly decomposed to very strong pressure, part of the mercury being then forced out, taining a larger portion of the other metals remaining behind. In the formation of amalgams is attended with little or no contraction ase of silver and copper, however, the contraction is considerable— and a few others, it is perceptible. The union of mercury with m is attended with considerable evolution of heat.

ombining mercury with other metals are:

ercury into direct contact with the other metal, either in the solid

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state or finely divided, the action sometimes takin
sometimes requiring the assistance of heat.

2. The introduction of metallic mercury into the s
part of the mercury then passing into the solution a
which then unites with the rest of the mercury. I
be more easily effected by means of an amalgam
sodium for example. A sodium-salt is then formed,
on the mercury and unites with it.

3. The introduction of various metals into solu
example. In the case of silver, gold, or platinum,
mercury from its solutions, the action must be
zinc or iron into the solution, and bringing it in co
form a voltaic circuit: thus a drop of solution of me
gold will not amalgamate it; but if an iron wire or
the wetted surface of the gold, a white spot of ama
point of contact.

4. By placing the metal to be amalgamated in
dilute acid, a voltaic circuit being also formed in th
is wetted with dilute sulphuric acid, and mercury p
ately amalgamated.

Several amalgams are used in the arts. Tin amalg
amalgams of gold and silver in the processes of gildi
amalgams, copper-amalgams, and an amalgam of
stopping teeth; an amalgam of zinc and tin, somet
used for coating the rubbers of electrical machines.

Aluminium-amalgam?—Klauer (Ann. Ch.
sium-amalgam laid on a lump of alum, decompose
siderable quantity of aluminium. Böttger (J. p
obtain an amalgam of aluminium in this manner; an
aluminium is not susceptible of amalgamation.

According to Cailletet (Compt. rend. xliv.
platinum) may be superficially amalgamated by co
amalgam and water; also when it is immersed in
metallic mercury forming the negative pole of a volt

Ammonium-amalgam. See i. 188.

Antimony-amalgam is said to be formed by t
in contact with 1 part of fused antimony; or by t
mortar with a small quantity of hydrochloric acid,
mercury. It is soft, and is decomposed by contac
separating in the form of a black powder.

Arsenic-amalgam.—Bergmann states that
cury to 1 pt. arsenic is produced by heating and trit

Barium-amalgam may be prepared by the galv
decomposing a saturated solution of chloride of bar
a soft pasty mass, in which a few sandy grains may
by water, and must therefore be kept under rock-oil.

Bismuth-amalgam.—Mercury amalgamates b
tures; but the amalgam is more quickly formed by
1 pt. of melted bismuth. The amalgam, which i
crystallo-granular. Sodium-amalgam in contact wit
or immersed in a solution of that salt, forms a co
hydrogen, and separation of black pulverulent bismu
of bismuth takes away but little of the fluidity of
adulterating that metal; according to Lucas, howe
adulterated with only $\frac{1}{8000}$ pt. of bismuth forms a
air. 1 pt. of bismuth dissolved even in 1,200,000 pt
the addition of potassium-amalgam and water, the
galvanic action in the form of a black powder, and
vessel. (Serullas, Ann. Ch. Phys. [3] xxxiv. 192.

Cadmium-amalgam.—Mercury combines readi
temperatures, forming a silver-white granular amalga
hard, brittle, heavier than mercury, and melting at
pletely saturated with cadmium, the amalgam cont
pts. cadmium, agreeing with the formula Hg^2Cd
introduced into a solution of cadmium is converted int

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am.—Produced by the action of a powerful voltaic battery on
n contact with mercury; also, according to Klauer, by the action of
calcium-salts.

m is not easily prepared by the action of sodium-amalgam on
much as a considerable quantity of cobalt-oxide is thereby pre-
immerses an amalgam of 5 pts. mercury, and 1 pt. zinc in an acid
loride supersaturated with ammonia; pours the liquid off after a
poses it with fresh portions of zinc-amalgam as long as any gas
and lastly, removes the excess of zinc by dilute sulphuric acid.
thus obtained is silver-white, soft and dull; is attracted by the
it contains zinc (?), and becomes covered with black, pulverulent
exposed to the air.

m may be formed: 1. By immersing a piece of copper-foil in a
of mercury.—2. By triturating mercury with common salt and
turating 2 pts. of mercury, 2½ of verdigris, and 1 of common salt
y of heated vinegar, which must be renewed as it evaporates, and
m by washing.—4. By mixing 1 pt. of finely-divided copper—ob-
ne oxide with hydrogen, or by precipitation from the sulphate by zinc
rops of mercurous nitrate, and then triturating with 3 pts. of mercury,
is formed (Berzelius).—5. Mercury placed in contact with the
taic battery, and covered with solution of cupric sulphate into which
s, becomes perfectly saturated with copper (Grove, Phil. Mag. [3]
o Joule (Chem. Gaz. 1850, p. 339), the amalgam thus obtained has
Hg; and the same definite compound is obtained by dissolving
and removing the excess of the latter by strong pressure (Chem.
When, however, the pressure is very strong, or is continued for a
ting amalgam contains more than 1 at. Cu to 1 at. Hg (Joule,
82).—6. Copper amalgam may also be formed by treating a solu-
te with sodium-amalgam (Klauer), or zinc-amalgam (Damour).
mersed in a mixture of cupric sulphate and sal-ammoniac forms a
llow amalgam of copper and ammonium, which soon decomposes.
am used by the Parisian dentists for stopping teeth is prepared by
s sulphate (obtained by heating together 10 grms. of mercury and
lphuric acid) and finely-divided copper (obtained by precipitating a
. cupric sulphate in 10 or 12 times its weight of water, with metallic
are triturated together under hot water for 20 or 30 minutes; the
f, and the trituration repeated with fresh quantities of water as long
any blue colour. The amalgam is then dried, again triturated, then
rmed into small cakes, which become quite hard in 36 to 48 hours.
oduced contains 3 pts. copper to 7 pts. mercury. An easier mode of
isten the precipitated copper with solution of mercurous nitrate,
upon it, and incorporate the required quantity of mercury by tri-
which is brittle at first, gradually softens under the pressure of the

nich becomes quite hard by keeping, is distinguished by the pro-
nd acquiring the consistence and elasticity of clay by continued
g, and recovering its hard crystalline character when left to itself
may then be pulverised, exhibits a granulo-crystalline fracture,
n to engrave upon tin. When heated it swells up, and small
show themselves on its surface, sinking into the mass again
urating the warmed lumps in a mortar, the amalgam is again
of a highly plastic almost unctuous mass. Its density is the same
hard state, so that it does not expand or contract in hardening, and
s air-tight when hard, into which it has been pressed in the soft
unt of this property that the amalgam is used for stopping teeth;
it contains renders it decidedly objectionable for that purpose.
advantageously used for sealing bottles, glass tubes, &c., in cases
ubstances, cork, &c., cannot be used.

am is obtained as a semi-fluid mass by decomposing a concen-
lio-iridic chloride with sodium-amalgam.

.—See GOLD, ALLOYS OF (ii. 927).

—Mercury and iron do not unite readily. A viscid amalgam is,
immersing sodium-amalgam containing 1 per cent. sodium in a
ion of ferrous sulphate. In small globules it is attracted by the
slowly heated on a watch-glass, exhibits the vivid sparkling of

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burning iron (Böttger). According to Aikin, iron-amal
of zinc-amalgam on ferrous chloride; but according to Da
in this way. Joule (Chem. Gaz. 1859, p. 339; Chem. S
amalgams of iron by the electrolysis of a solution of fe
pole being formed of mercury. The following table e
physical character of the compounds thus produced.

No.	Composition.		Specific gravity.	
	Mercury.	Iron.		
1.	100	0·143	. .	Perfectly flui
2.	„	1·39	. .	Fluid.
3.	„	2·97	. .	Semi-fluid.
4.	„	11·8	12·19	Soft.
5.	„	18·3	. .	Solid: colour
6.	„	47·5	. .	Solid: good
7.	„	127·6	10·11	Solid: frable.
8.	„	14·74	. .	The superflu the semi-f
9.	„	79	. .	Compressed fifty tons
10.	„	103·2	. .	Ditto.

Lead-amalgam.—See LEAD, ALLOYS OF (p. 534).

Magnesium-amalgam.—Magnesium combines wit
and forms a solid amalgam, even with large quantitie
2. The amalgam may also be obtained by electrolysis.—
sodium-amalgam with solution of sulphate of magnesium (
89).—The amalgam thus obtained oxidises slowly in pur
water. (H. Davy.)

Manganese-amalgam is obtained by the action of
solution of manganous chloride. It is viscid, with roug
heated in contact with the air, gives off mercury, tarnis
paste, and finally leaves brown manganoso-manganic oxi

Nickel-amalgam is obtained like cobalt-amalgam.
the magnet; decomposes when exposed to the air, the
nothing but mercury is left; may be mixed with a larger
up its nickel to hydrochloric and dilute sulphuric acid.

Osmium-amalgam is formed, according to Tenn
osmic acid with metallic mercury; it is more or less fluid
of mercury contained in it.

Palladium-amalgam is formed by agitating the sol
excess of mercury. The amalgam containing Pd^2Hg is a
to Berzelius, does not give off its mercury below a white

Platinum-amalgam.—Platinum in the compact state
spongy platinum unites with it when the two are triturate
or in contact with a small quantity of acetic acid. The a
formed by immersing sodium-amalgam containing 1 per c
solution of platinic chloride; sodium-amalgam also co
monium into platinum-amalgam, with evolution of am
amalgam is silvery, and does not give off mercury below
Joule (Chem. Soc. J. xvi. 384), by electric deposition
obtained amalgams exhibiting the following composition

Mercury.	Platinum.	Specific gravity.	
100	15·48	14·29	Met
„	21·6	. .	Soli
„	34·76	14·69	Dar

An amalgam of 12 platinum to 100 mercury has a brig
and greasy to the touch. Pressed with a force of 12 ton
a hard button of dark grey amalgam containing 43·2 pt
Joule infers from these results that the solid amalgam

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ercury has the composition $PtHg^2$. A thick pasty amalgam of ained by exposing mercury for some time to the action of platinic

lgam.—1. The two metals unite even at ordinary temperatures, g attended with great evolution of heat (H. Davy). 2. When a cup connected with the negative pole of a voltaic battery of at covered with a strong solution of potash in which a piece of is immersed, and into which the positive wire dips, the mercury Berzelius). 1 pt. of potassium forms with 30 pts. of mercury fter cooling, is tolerably hard and brittle; with 70 pts. mercury malgam which is solid at ordinary temperatures, but with more a liquid amalgam (H. Davy). According to Gay-Lussac and am is solid and crystalline when it contains from 70 to 96 pts. of otassium, but liquid when the proportion of mercury amounts to Böttger (J. pr. Chem. i. 303), the amalgam is perfectly solid pts. of mercury to 1 pt. of potassium; with 140 mercury, it is nercury, friable and partly crystallised; with 200 mercury, viscid. ises in cubes (Berzelius and Pontin). The solid amalgam eated. It gives off its mercury below a red heat (H. Davy). air or immersed in water, it is resolved into mercury and aqueous being slowly evolved; a similar change is produced by aqueous h moist ammoniacal salts, it is resolved into a potassium-salt and . It easily gives up its mercury to iron and platinum. (H.

—A native compound of mercury and of silver, called 'amalgam' having the composition Ag^2Hg^2 or Ag^2Hg^3, is found crystallised ic dodecahedrons, and other forms of the regular system, with in traces; also massive. Hardness = 3 to 3·5. Specific gravity and streak silver-white; opaque; fracture conchoidal; brittle, und when cut with a knife. Klaproth found in amalgam from the Palatinate, 36 per cent. silver and 64 mercury, agreeing Hg^2. Heyer, on the other hand, found in amalgam from the per cent. silver, agreeing with Ag^2Hg^3; and a specimen from , analysed by Cordier, exhibited nearly the same composition, lver. Amalgam also occurs at Rosenau in Hungary, Sala in Spain, and in Chile. A native silver-amalgam called *Arquerite*, Arqueros, Chile, contains, according to Domeyko, 13·5 per cent. ry, giving the formula Ag^2Hg^6.

by silver slowly at ordinary temperatures, but quickly when the thin lamina, or in powder, is introduced at a red heat into heated ercury immersed in a solution of silver-nitrate, precipitates the crystalline amalgam, called a silver tree, or *Arbor Dianæ*. The be somewhat acid, and not too much concentrated. A soft ied by the action of sodium-amalgam on a strong solution of

lgam varies in character, according to its composition and the rmation, being sometimes a soft, or crystalline, or granular mass; f ramifications of prismatic crystals placed end to end. Joule m most readily formed by the action of mercury on nitrate of ige, the composition Ag^2Hg. When the action is assisted by ie negative pole of a voltaic battery, amalgams richer in silver ean composition of the amalgam, after being subjected to a the square inch, was 43·71 silver to 100 mercury. The com- d silver is attended with a considerable contraction of volume.

.—Sodium combines rapidly with mercury at ordinary tempera- being attended with a hissing noise and vivid combustion énard, *Recherches*, i. 246). A piece of sodium forcibly thrown vn out of the vessel with explosion, in consequence of the great llas, Ann. Ch. Phys. [2] xl. 328). To form the amalgam, the riturated together in a dry mortar fitted with a cover, and the rock-oil as soon as the combustion is over (Böttger). The r of mercury. When it contains 30 pts. of mercury to 1 pt. of hard under the file, which wears it away in the form of powder; e, laminar fracture. When it contains 40 pts. of mercury, it is nan with 30 pts. (Lampadius). An amalgam containing 60 . of sodium forms a stiff paste at 21° (Böttger). 64 pts. of

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structure (Gay-Lussac and Thénard). 80 pts. mercury t
21° (Böttger). 86 mercury to 1 sodium: a mass conta
granular crystals (Gay-Lussac and Thénard). 100 me
viscid, and consisting of a solid and a liquid portion (Böttg
1 sodium: liquid (Gay-Lussac and Thénard). Sodium-
same reactions as potassium-amalgam. It likewise amalgama
(H. Davy). It decomposes the salts of barium and stront
metallic salts, when a small quantity of water is present, the pro
of mercury with the heavy metal (Böttger, J. pr. Chem. iii.
used as a reducing or hydrogenating agent for effecting the su
for chlorine, bromine, &c., in organic compounds.

Amalgam of Potassium and Sodium.—5 pts. potassium and
together by heating them under rock-oil, form an alloy which
9°, but when brought in contact with 100 pts. of mercury, u
very solid mass. (Böttger.)

Strontium-amalgam.—Prepared like that of barium, v
decomposes more quickly under a mixture of the solutions of ch
chloride of calcium, as well as under water. When exposed to
hours, it is converted into carbonate of strontium, with separati

Tellurium-amalgam.—Mercury and tellurium are said
ing a tin-coloured amalgam.

Thallium-amalgam. — The two metals unite readily,
amalgam. (Crookes.)

Tin-amalgam.—Mercury and tin unite quickly, even at
still more quickly on pouring mercury into melted tin. A piec
of which is immersed for four weeks in mercury, is penetrate
by the mercury, and exhibits cracks; its lower end becomes at
the metal, and the immersed part is found to be covered with
of which float about in the mercury. If a square bar of tin, w
form, or hammered or filed square from a round bar, be kept
mercury, it splits in directions proceeding from the lateral
diagonals, thereby dividing itself into four triangular prisms
knife; at the same time, a four-sided pyramid is formed at each
If the piece of tin has any other form, cracks are produc
(Daniell, J. of Roy. Inst. i. 1). Sodium-amalgam immersed
tion of stannous chloride, yields a viscid amalgam of tin. (Bö

Tin-amalgam has a tin-white colour; and if the mercury is
is brittle, granular, and according to Daubenton. crystallises in

Sn^2Hg and SnHg do not fuse till heated above 100°. (Reg

Sn^2Hg has at 26° a specific gravity of 8·8218; Sn^2Hg, 9·
$SnHg^2$, 11·3816. 1 vol. of tin with 1 vol. of mercury forms
gravity at 27° is 10·4729; 1 vol. tin with 2 vol. mercury, 11·46
3 vol. mercury, 12·0257. In most cases, therefore, condensati
single instance of 1 vol. tin to 2 vol. mercury, however, this c
perceptible. (Kupffer, Ann. Ch. Phys. [2] xl. 293.)

The compound obtained by fusing 4 pts. of tin with 1 pt. of
versed after cooling, a kind of mosaic silver, which, when rul
stone, acquires the metallic lustre. The *silvering* of mirrors i
of tin.

Joule obtained beautiful crystalline amalgams by making
solution of stannous chloride. The amalgam containing 100
had a specific gravity of 10·518; that containing 100 mercury
gravity of 10·94: hence the combination is attended with c
The amalgam of tin is decomposed by pressure, the mercury le
high pressure having a volume little more than one-eighth of th

An amalgam of *tin* and *bismuth* is obtained by melting toget
of bismuth, and 1 pt. of mercury.

An amalgam of 2 pts. *tin* and 1 pt. *cadmium* is used for sto
metals are melted in an iron ladle, slightly warmed; mercur
is poured into an iron mortar, and rubbed with a wooden pestle
buttery consistence; and the excess of mercury is squeezed out
residue is almost granular, but becomes soft and plastic when h

An amalgam of *tin* and *lead* may be formed by introducing
metals into mercury.

Amalgams containing *tin*, *lead* and *bismuth* are described und

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bismuth, 5 lead, 3 tin, and 7 or 8 mercury is recommended by
e rubbers of electrical machines.
in, silver and *gold* is also used as a cement for the teeth. It i
together 1 pt. gold and 3 pts. silver, adding 2 pts. tin to the
sing the resulting alloy, and kneading it together with an equal

—When zinc-filings are triturated with mercury, at ordinary
nation takes place slowly; at a higher temperature, still somewhat
nt of mercury, the metals combine easily, and still more readily
ed with melted zinc. A bar of zinc, immersed to half its length
ays, becomes pointed at bottom, and covered, especially on the
mersed end, with six-sided tables of the amalgam (Daniell).
in contact with mercury and a dilute acid, a galvanic action is set
zinc becomes covered with mercury, which then penetrates into
verts the whole of the metal into an amalgam. As soon as the
covered with mercury, the evolution of hydrogen ceases; but it
ging the amalgam in contact with iron, copper, or platinum, to
ercury is then transferred (Döbereiner). Sodium-amalgam
ntrated solution of sulphate of zinc, forms a viscid amalgam of

sually prepared by cooling melted zinc to as low a temperature as
solidifying, and then pouring in the mercury in a fine stream,
constantly stirred. If this precaution be neglected, part of the
into vapour, sometimes throwing the melted metal about.
mercury: very brittle.
5 pts. mercury form an amalgam sometimes used for coating the
achines; it is brittle and pulverulent.
mercury: tin-white, granular, brittle; melts at the boiling point
not give off mercury till raised to a higher temperature. At a
repitates strongly; at a stronger red heat, it burns with great
manent in dry air. Cold dilute nitric acid decomposes it readily,
ry unaltered till all the zinc is dissolved. Dilute sulphuric and
on it but slowly. Ammonia and sal-ammoniac also dissolve out
and form water. Zinc-amalgam immersed in the solution of a
ium, uranium, manganese, or iron, merely throws down the oxide;
lutions of cobalt, nickel, and copper, it precipitates the metal,
s with the mercury. (Damour, Ann. Min. [3] xv. 41; also
5.)
richer in mercury, six-sided laminæ containing 2 pts. zinc and 5
t on cooling. The portion which remains liquid is a solution of
rcury. 1 pt. of zinc dissolved in 8,000 pts. of mercury may be
x powder which forms on the surface when the mercury is agitated
ir.
mersed in caustic potash liberates pure hydrogen. When zinc
d in aqueous ferrous chloride, and a crystal of a nitrate is placed
t is gradually formed on the surface of the amalgam, consisting
ch is immediately taken up by the mercury. The presence of
to the production of this effect; chlorates and other salts do not
e, Pogg. Ann. ix. 479.)
rolytic method, has obtained amalgams of zinc having the following
perties:

Zinc.	Specific gravity.	
39·4	11·34	White and crystalline.
122·8	8·935	,,
134·9	8·349	Prepared from hot sulphate of zinc.

y of the first of these amalgams indicates a certain contraction
ppears to decompose it, mercury being expelled till the amalgam
t. Hg to 3 at. Zn.
nd *zinc* are used for coating the rubbers of electrical machines
nds as the best proportion; 1 pt. zinc, 1 pt. tin, and 2 pts. mercury,
2 pts. zinc, 1 pt. tin, and 3½ to 6 pts. mercury.

NTIMONIDE OF. See page 886.

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MERCURY, ARSENIDE OF. See page 886.

MERCURY, BROMIDES OF. Mercury forms two br
as *mercurous* and *mercuric*.

α. **Mercurous Bromide.** (Hg^2)″Br^2.—This compound
subliming an intimate mixture of 1 at. mercury and 1 at. mercuri
2. By precipitating mercurous nitrate with aqueous bromide of
When prepared by the first process, it forms a fibrous mass (
which are yellow while hot, but become whitish on cooling (
xv. 56). By (2): white powder (Balard); yellowish-white
Specific gravity 7·307 (Karsten). It is tasteless and inodor
tilises undecomposed at a low red heat.

When heated with *phosphorus*, it is resolved into bromide of
phide of mercury (Löwig). Treated with cold aqueous *ammo*
with water containing ammonia, it leaves a grey powder, which
mercury, and when heated, gives off ammonia, and yields a
mercurous bromide, and mercuric bromide (Rammelsberg).
yields mercurous oxide and bromide of potassium. When boile
or *chloride of ammonium*, it yields a solution of mercuric brom
metallic mercury (Löwig). It is not perceptibly soluble in c
or *succinate of ammonium*, while the same liquids, when hot, di
facility, leaving, however, a grey-pulverulent residue [metalli
perceptibly soluble in *sulphate* or *nitrate of ammonium*, even
(Wittstein.)

β. **Mercuric Bromide.** Hg″Br^2.—1. Mercury unites with
temperatures, forming this compound, the combination being
lution of heat, but not of light (Balard).—2. The same co
agitating mercury with water, adding bromine as long as its col
boiling, filtering, and leaving the solution to crystallise.—3.
oxide in hot aqueous hydrobromic acid, and leaving the solution
subliming mercuric sulphate with bromide of potassium (Lö
contains also mercurous bromide (O. Henry).—5. By mixi
nitrate with bromide of potassium, evaporating as long as
crystallises out, and purifying the product by solution in alcoho
evaporated to dryness leaves a residue, from which boiling
small quantity of the compound. (Löwig.)

Mercuric bromide crystallises from the aqueous solution in soft
the alcoholic solution in white needles (Löwig.) According
1859, p. 226), the crystals are rhombic prisms, ∞P . oP, cle
and having the angles ∞P : ∞P = 68° 24′ and 111° 26′.
with sublimed mercuric chloride. The product obtained by (5)
strong heat, a specific gravity of 5·9202 (Karsten). Mercur
sublimes when heated. It dissolves in 94 pts. *water* at 9°
4 pts. of boiling water, the greater part separating as the liqui
solution reddens litmus. It dissolves very easily in *alcohol*, stil
With *phosphorus* it forms bromide of phosphorus. Heat
arsenic, it gives up its bromine. Its aqueous solution exposed
in contact with *mercury* or *copper*, or mixed with *cuprous bromi*
bromic acid, deposits mercurous bromide. With a small quant
it yields a white, and with a larger quantity a black pr
With *ammonia* it forms a white, with fixed alkalis a yellow
Hypochlorite of sodium added to the solution throws down
(Rammelsberg), and hypochlorous acid converts mercuric
chloride and bromate, the action being attended with evolution o
(Balard). Heated with *nitric* or *sulphuric acid*, it gives o
(Balard); but according to H. Rose (Analyt. Chem.) it i
sulphuric acid.

Double Salts of Mercuric Bromide.—Mercuric bro
more basic metallic bromides, forming easily soluble double salt
bromohydrargyrates), losing thereby its power of reddening
taining the bromides of the alkali-metals are crystallisable.

Ammonium-salt.—Mercuric bromide dissolves abundantly in
ammonium. Alkaline carbonates added to the solution throw d
curammonium. (Löwig.)

The *barium-salt* crystallises in highly lustrous prisms, whic
air. (Bonsdorff.)

Calcium-salt.—A solution of bromide of calcium saturated w

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is evaporations, at first tetrahedrons and octahedrons, which have permanent in the air, and are decomposed by a small quantity of completely when heated and crystallise out again on cooling. If carried further, prisms or needles are obtained, which deliquesce onsdorff.)

ferric or ferrous] forms yellowish very deliquescent prisms.

—A solution of mercuric bromide and bromide of magnesium on over oil of vitriol, first broad thin laminæ, permanent in the air ining $MgHg^2Br^6$?, then very deliquescent crystals containing dorff.)

lt crystallises in light red very hygroscopic prisms.

A solution of the salt $KHg''Br^3$ or $KBr.Hg''Br^2$ is obtained by noderately concentrated solution of bromide of potassium with n anhydrous yellow octahedrons (Löwig), in flat rhombic prisms air and containing 1 at. water. The crystals melt when heated, e of mercuric bromide (Löwig). A solution of equal parts of this f potassium yields the salt K^4HgBr^6 (?) in prisms which are r. (Bonsdorff.)

rystallises partly in needles, partly in rhombic prisms, and deli-

-*α*. $SrHgBr^4$ or $SrBr^2.HgBr^2$ forms crystals soluble in water in all Hg^2Br^6 or $SrBr^2.2HgBr^2$. A solution of 1 at. bromide of strontium f water, takes up at 50°, 3 at. mercuric bromide, and the solution 1 at. mercuric bromide and then yields small crystals of the salt *β*.

rystallises in prisms and tables deliquescent in moist air.

HLORIDES OF. Mercury forms two chlorides, analogous to

oride. $(Hg^2)''Cl^2$.—*Hemichloride, Dichloride, Subchloride, Proto-e of mercury; Calomel; salzsaures Quecksilberoxydul, versüsster Quecksilber, Kalomel; Chloretum hydrargyri, Hydrargyrum mu-urius dulcis*, s. *kalomelanicus*, s. *loticus, Draco mitigatus, Aquila cœlestis*, s. *Mercurii, Panacea mercurialis*, s. *cœlestis*, s. *Mercurii; rcure.*

found native, as *horn-quicksilver*, in dimetric crystals exhibiting the ∞, like figure 227 (ii. 135), also with ∞P, P∞ and oP. Length = 1·744; P : P in the terminal edges = 98° 7′; in the lateral It occurs also in crystalline coats and granular. Hardness = 1 to = 6·482. It has a dirty white colour and adamantine lustre, hed; translucent in thin splinters. Sectile. Fracture conchoïdal. nnabar, at Moschellandsberg in the Palatinate, also at the quick- and Almaden, and at Horzowitz in Bohemia.

de is produced: 1. By the direct combination of mercury and rdinary temperatures, more quickly at the boiling heat of mercury, ng then attended with a yellowish red flame, and mercuric chloride ned.—2. By heating mercuric chloride with metallic mercury. sulphurous acid and other reducing agents on mercuric chloride. rcury with a solution of ferric chloride, the action being accelerated ree hydrochloric acid.—5. By the action of hydrochloric acid on by precipitating a mercurous salt with a soluble chloride.

rcurous chloride in the pulverulent form, called calomel, is ex-edicine. It may be prepared either in the dry or in the wet way. .—1. By triturating 4 pts. (1 at.) of mercuric chloride with 3 pts. he mixture being moistened with water or alcohol, and the tritu-ll the mercury has lost its fluidity—then gradually heating the sk or retort till it sublimes. A large portion of the mercuric chloride omel during the trituration. Trautwein heats the deadened mix-for a few hours, and pulverises it once more before sublimation. intimate mixture of equal parts of mercurous sulphate and common

$$Hg^2SO^4 + 2NaCl = Na^2SO^4 + Hg^2Cl^2.$$

im. lxvi. 168) triturates 8 pts. of mercury, 18 pts. of dry monobasic nd 6 pts. of water, till the fluidity of the metal is destroyed, and

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heats the resulting mercurous sulphate with an equal weight o
sublimate is obtained.—3. By deadening 2 at. mercury with 2 a
at. peroxide of manganese, and heating the mixture to sublimati
acid:

$$Hg^2 + 2NaCl + MnO^2 + 2H^2SO^4 = Hg^2Cl^2 + Na^2SO^4 +$$

4. By triturating mercury with common salt, ferric sulphate, ar
water, till the metal has lost its fluidity, and subjecting the mi
(Schaffhäutl), Ann. Ch. Pharm. xliii. 25.) The basic ferric su
as a waste product, may be made available for this process; a s
chloride may sublime together with the calomel (Schaffhäu
probably:

$$Fe^2(SO^4)^3 + 6NaCl + Hg^2 = 3(Na^2SO^4) + 2FeCl^2$$

The calomel set free in the form of vapour by either of thes
either allowed to collect in the form of a dense, fibrous sublin
carefully pulverised; or the calomel vapour is cooled under such
solidifies in the form of a soft powder instead of a solid cake. T
according to Jewel and O. Henry (J. Pharm. viii. 545), by causi
to pass into a chamber into which vapour of water is inject
According to the process now adopted in this country, on the oth
or the ingredients from which it is prepared, is heated in a cas
long and 1 foot wide, one end of which is provided with an openin
and remove the materials, and closed during the operation, wh
minates in a contracted neck which opens into the upper part
4 feet long and broad, and 6 feet high. In this chamber the
the form of a soft powder. As the iron of the tube decomp
calomel, a small quantity of mercuric chloride is added to th
J. Pharm. [3] iii. 121). Soubeiran (J. Pharm. xxix. 502) ad
excepting that he heats the materials in an earthen retort, an
vessel as a condensing chamber. The pulverulent calomel obtai
processes is washed with a large quantity of warm water, or
warm alcohol, to free it from the corrosive sublimate with wh
taminated.

6. *In the wet way.*—1. By precipitating a warm dilute solution
with excess of common salt or sal-ammoniac, and washing the
with cold water. The calomel obtained by this process, first p
is in the form of a remarkably fine powder, and has conseque
active medicinal properties than the ordinary preparation. Its
may perhaps be partly due to an admixture of basic mercurou
oxide, which, according to Buchner, Mialhe, and others, are s
This admixture, however, does not occur if the solution of mercur
diluted, and, if necessary, filtered, before being mixed with the
if the common salt or sal-ammoniac be added in excess, and
some time in contact with the precipitate. To the same end,
and Trautwein (Repert. Pharm. xi. 72; xii. 155) recommer
acid be added to the mercurous solution before mixing; and Ch
addition of hydrochloric acid to the solution of common salt. I
the liquid must not be heated so much, as, otherwise, part of the
dissolved in the form of mercuric chloride. According to Dumas,
by the use of common salt always contains more or less of that s
be freed from it by washing; the presence of the salt renders the c
more soluble than that obtained by sublimation; but Mialh
586) found only traces of common salt, and no difference in th
phurous acid gas, evolved by heating sulphuric acid with charco
solution of mercuric chloride saturated at 50°. The reaction is a

$$2HgCl^2 + SO^2 + 2H^2O = Hg^2Cl^2 + 2HCl + H$$

The filtered liquid still contains a certain quantity of undecompos
and. therefore, still gives a precipitate of calomel when heated
to the boiling point (Wöhler, Ann. Ch. Pharm. xc. 124). Acco
(*ibid.* xcvi. 325), the decomposition is almost complete in the fir
the solution is sufficiently dilute (1 pt. mercuric chloride to 80
saturated with sulphurous acid is heated for some time to 70°
requires a product of 84 per cent.; experiment gave 84·6 per cen
Impurities and Adulterations.—1. *Mercuric chloride:* Cold wat
with the powder for some time and then filtered, turns brow

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2. *Basic mercurous* or *mercuric nitrates*: Red fumes evolved ce in a flask or tube till it sublimes. 3. *Metallic mercury:* Grey rcury discernible under the microscope. 4. Pounded *heavy spar* s remain behind on sublimation. 5. *Gum* and other organic natic odour on the application of heat; solubility in water or

ed calomel crystallises in dimetric forms like the native mineral, erally united in fibrous masses. Specific gravity of the artificial rsten); 7·140 (P. Boullay). Vapour-density, according to tion, 8·35; by calc. for HgCl, 8·25 $\left(=\frac{200 + 35{\cdot}5}{2} \times 0{\cdot}0693\right)$.

slucent, and has a very high refractive and dispersive power; it llow colour when heated in the state of powder. Precipitated vy powder, with a tinge of lemon-yellow. Calomel volatilises out previous fusion. According to Faraday, it does not volatilise res. It is tasteless and inodorous, and may be regarded as quite or, according to Pfaff, a perceptible precipitate is produced in s nitrate by hydrochloric acid diluted with 250,000 pts. of water.

Calomel becomes dark grey on exposure to light.—2. Heated *horus-vapour*, it yields phosphite of mercury and trichloride of). 3. When heated with a small quantity of *sulphur*, it yields chloride; with a larger quantity of sulphur, the products are of sulphur:

$$Hg^2Cl^2 + S = HgCl^2 + HgS$$
and $$Hg^2Cl^2 + S^4 = 2HgS + S^2Cl^2$$

cold aqueous *sulphurous acid*, it turns grey, and in the same eat it becomes greyish-black, from loss of chlorine. In this no metallic mercury can be discovered with the lens; but when nto calomel and metallic mercury; it is probably, therefore, a l).—5. Calomel gives up its chlorine to many *metals*, both in the y. On boiling it with *copper* and water, a green solution is e copper becomes covered with a black film, from which hydro- upric oxide, leaving a residue of metallic mercury (A. Vogel,).—6. By aqueous *stannous chloride*, it is reduced to the metallic at ordinary temperatures, but quickly on boiling (A. Vogel,).—7. With *trisulphide* (*mineral kermes*) *or pentasulphide of an-* y converted into black sulphide of mercury and trichloride of el triturated with *iodine* and water, yields mercuric chloride, mercuric iodide, of which the water takes up a small portion. erain, J. Pharm. xii. 651.)

$$Hg^2Cl^2 + I^2 = HgCl^2 + HgI^2.$$

aqueous solutions of the *iodides of the alkali-metals, magnesium* rk green mercurous iodide, and an aqueous metallic chloride. thus produced remains unchanged for a long time in the dark; ight it first becomes yellow, and then red from loss of mercury— wn liquid—gives off mercury and mercuric iodide—and leaves etallic chloride, together with the excess of metallic iodide J. Pharm. iv. 329). 10. Hot *nitric acid* dissolves calomel, with de gas, forming a solution of mercuric chloride and mercuric

$$+ 4HNO^3 = 3HgCl^2 + 3HgNO^3 + 2H^2O + NO.$$

ither dissolves nor decomposes calomel, even after a long time; dissolves it (the liquid solidifying to a white saline mass on phurous anhydride, yielding a sublimate of mercuric chloride, and ercuric chloride mixed with mercuric sulphate. (A. Vogel.)

$$+ 2H^2SO^4 = HgCl^2 + HgSO^4 + SO^2 + 2H^2O.$$

l in aqueous *hydrocyanic acid* yields metallic mercury and a cyanide of mercury and hydrochloric acid (Scheele, Opusc. ii. omel, however, remains undecomposed, or, at least, undissolved, f hydrocyanic acid is present; the undissolved portion is not a black powder which, when heated, gives off calomel vapour, quantity of permanent gas, and leaves a carbonaceous powder

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(Soubeiran, J. Pharm. xv. 523). The decomposi
fore be more complicated than that which would h

$$Hg^2Cl^2 + 2HCy = Hg +$$

and deserves further examination; to the medical
that the mild substance calomel is converted by
which acts so violently as cyanide of mercury.—
alkalis, yields mercury, oxygen gas, and a chloride

$$Hg^2Cl^2 + 2KHO = 2KCl +$$

By *aqueous fixed alkalis* it is converted into black
alkali-metal remaining in solution. Calomel likewise
ammonia, not, however, by conversion into mercur
curosammonium (NH^2Hhg)Cl. The supernatant
quantity of mercury in solution. *Carbonate of a*
quickly dissolves it, with the exception of a small
Carbonate of magnesium exerts no action in the co
but at the boiling heat, carbonic anhydride is evolv
formed, containing mercuric oxide in combination
Pharm. iii. 31; iv. 289). According to A. Voge
calomel heated with water and *carbonate of calciu*
mercurous (and mercuric ?) oxide and metallic
evolved and chloride of calcium formed. The ca
act in a similar manner, but not so strongly. W
gypsum, chloride of calcium and mercuric sulph
produced by boiling with *sulphate of sodium*.—
water, calomel is partly converted into metallic m
calomel with excess of mercury and soluble merc
chloric acid quickly converts calomel into mercu
On the other hand, when water containing hydr
vessel with calomel, the calomel is completely conv
separation of mercury.

Chloride of potassium, *chloride of sodium*, and
convert calomel into mercuric chloride, and unite
Hence calomel should never be prescribed for inte
of these alkaline chlorides, especially sal-ammonia
this and other reactions of calomel, see *Gmelin's H*

Compounds of Mercurous Chloride.—α. C
calomel absorb 7·38 pts. ammonia-gas, forming the
pound is black, but gives off ammonia on expo
mercurous chloride (H. Rose). See MERCURY-BA

β. With *Chloride of Sulphur*. $Hg^2Cl^2.SCl^2$.—
27 pts. mercuric chloride and 6 pts. washed and
heating the mixture in a porcelain dish covered wi
in slender crystals. These must be taken out afte
as long as any efflorescence is produced. The co
mixing calomel and dichloride of sulphur to a stiff
the mixture after it has stood for twenty-four hou
then distils over first; afterwards the mass gradua
and finally the salt sublimes in right rectangul
tion: they are yellowish white when cold, and a
(Capitaine, J. Pharm. xxv. 525 and 566.)

γ. With *Platinous oxide*.—This compound is
powder on mixing mercurous nitrate with platinic
chloride sublimes, and platinous oxide remains be

δ. With *Stannous Chloride*. $Hg^2Cl^2.SnCl^2$.—Pr
finely pulverised tin-amalgam (3 pts. tin to 1 p
filling a retort to about one-fourth with the mixture
rising to 250°. The mass when cold is pulveris
whereupon the double chloride sublimes in very sm
metallic mercury remains. The crystals are decom
Pharm. xxv. 549.)

ε. With *Sulphuric anhydride*.—Calomel absorbs
forming a white translucent mass. (H. Rose, P

Mercuric Chloride. $Hg''Cl^2$.—*Protochlorid*
Corrosive Sublimate; aetzender Quecksilber-sublim
chlorure de Mercure, Sublimé corrosif; Mercurius
corrosivum album.

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roduced:—1. By burning mercury in excess of chlorine gas.—
ury in aqua regia containing excess of hydrochloric acid, evapo-
residue in boiling water, and leaving the salt to crystallise by
lving mercuric oxide in hydrochloric acid, and in general by
of mercuric oxide or a mercuric salt with metallic chlorides.
the large scale by decomposing mercuric sulphate with chloride
ate mixture of equal parts of common salt and mercuric sulphate
pts. mercury with 5 pts. strong sulphuric acid, till the mixture
aline mass) is exposed to a gradually increasing heat, in a glass
ide neck, or better in a narrow-necked retort; mercuric chloride
cold part of the vessel, while sulphate of sodium remains behind.
tremely poisonous nature of the vapours, the process must be
mney having a good draught. The mercuric sulphate frequently
tity of mercurous sulphate, which is converted by the chloride of
to prevent this contamination, a small quantity of peroxide of
o the mixture; or 10 pts. mercury, 3 common salt, 3 peroxide of
ric acid and 3 water, are triturated together, and the mixture is
:

$MnO^2 + 2H^2SO^4 = HgCl^2 + Na^2SO^4 + MnSO^4 + 2H^2O.$

ethod is to mix a boiling concentrated solution of mercurous
ted hydrochloric acid as long as a precipitate is formed, and boil
tity of hydrochloric acid equal to that which was used for the
action is:

$(NO^3)^2 + 4HCl = 2HgCl^2 + 2H^2O + 2NO^2.$

g deposits the mercuric chloride in beautiful crystals.
rystallises in two forms, both belonging to the trimetric system.
separate from the alcoholic solution exhibit the combination
Ratio of axes $a : b : c = 0{\cdot}7254 : 1 : 1{\cdot}0686$. Angle $\infty P : \infty P$
principal section = 71° 55′; $\breve{P}\infty : \breve{P}\infty$ in the basal principal
or the crystals obtained by sublimation, $a : b : c = 0{\cdot}9347 : 1 :$
∞P, in the macrodiagonal principal section = 86° 8′; $\infty\breve{P}2$
$: \breve{P}\infty$ in the basal principal section = 37° 30′; $2\breve{P}\infty : 2\breve{P}\infty$ in
The crystals exhibit these faces together with $\infty\breve{P}\infty$. They
t various degrees of translucency up to complete transparency.
5·4032 (Karsten); 5·420 (Boullay). Vapour-density 9·8
calculation, 9·48 $\left(= \frac{200 + 2 \cdot 35{\cdot}5}{2} \times 0{\cdot}0693\right)$.

nelts at 265°, boils at 295°, and volatilises somewhat more easily
ordinary temperatures. It has a disagreeable metallic taste
rful acrid poison. It dissolves in *water*, *alcohol* and *ether*.
, 100 pts. water at different temperatures dissolve the following
chloride.

Quantity of salt dissolved.	Temperature.	Quantity of salt dissolved.
5·73	60°	13·86
6·57	70	17·29
7·39	80	24·32
8·43	90	37·05
9·62	100	58·96
11·34		

s much more soluble, requiring only $2\frac{1}{2}$ pts. at ordinary tempera-
he boiling point of alcohol; and it is almost equally soluble in
n aqueous solution of mercuric chloride is shaken up with ether,
greater part of it. Mercuric chloride volatilises in somewhat
with the vapours, when its alcoholic or ethereal solution is

lissolves in considerable quantity in boiling concentrated *hydro-*
solution solidifies on cooling to a crystalline mass having a
, which, however, becomes fluid again at the heat of the hand.
cording to Boullay, of an *acid mercuric* or *hydromercuric chloride*
exposed to the air, it effloresces, gives off the excess of acid, and
oride. Mercuric chloride likewise dissolves with great facility in
llises from the solution by cooling or evaporation. *Sulphuric*
on it.

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Many metals, viz. *arsenic*, *antimony*, *bismuth*, *zinc*, *tin*, *lead*, decompose mercuric chloride in the dry way, withdrawing the h chlorine, and separating calomel or metallic mercury, which la with the excess of the other metal. *Arsenic* forms trichloride sublimate. An intimate mixture of 3 pts. *antimony* and 1 well pressed into a glass, becomes hot and liquid in the course the application of heat, yields trichloride of antimony and heated with mercuric chloride yields a distillate of stannic ch due containing calomel and stannous chloride. Many metal from the aqueous or alcoholic solution of the chloride. Mo calomel together with the mercury; but *zinc*, *cadmium*, and but mercury, zinc being thereby converted into a semi-fluid forming an amalgam which crystallises in beautiful needles. of mercuric chloride in solution, see p. 900.

Compounds of Mercuric Chloride. α. With *Amm* chloride is gently heated in a stream of ammoniacal gas, the lat compound fuses by the heat evolved in the combination. The pro to contain $HgCl^2.NH^3$. This compound boils at 590°, and m loss of ammonia; it is decomposed by water.—(See MERCURY-

β. With other *chlorides*.—Mercuric chloride unites with many forming crystallisable double salts. They are prepared, for th the aqueous solutions of the two salts in the required proportio spontaneous evaporation.

Ammonium-salts.—One of these double salts has long been k It crystallises in flattened rhombic prisms, $2NH^4Cl.HgCl^2.H^2$ with the corresponding potassium-salt. When exposed to dry a without change of form. Kane has also obtained $NH^4Cl.Hg$ ½ at. water. $2(NH^4Cl.HgCl^2).H^2O$, the first in a rhomboïdal in long silky needles.—According to J. Holmes (Chem. New 25 pts. mercuric chloride and 1 pt. sal-ammoniac in hydrochlori of the salt $2NH^4Cl.9HgCl^2$; and on mixing this solution wit hydrochloric acid, or by dissolving in that acid a mixture of 3 and 1 pt. sal-ammoniac, the salt $2NH^4Cl.3HgCl^2.4H^2O$ is obtai

The *chlorides of barium* and *strontium* form well-crystallised co chloride, viz. $BaCl^2.HgCl^2.4H^2O$, and $SrCl^2.2HgCl^2.2H^2O$. *Ca* bines in two proportions with mercuric chloride. When the latte tion in chloride of calcium, tetrahedral crystals separate from tolerably persistent in the air, and contain $CaCl^2.5HgCl^2.8H^2O$. of these crystals, the liquid yields, when evaporated by a gen of large prismatic crystals, $CaCl^2.2HgCl^2.6H^2O$, which are very

The chlorides of *cobalt* and *copper* also form crystallisable d *lead* does not appear to form a double salt with mercuric chlori

The *iron-salt*, $FeCl^2.HgCl^2.4H^2O$, and the *manganese-sa* are isomorphous and crystallise in rhombic prisms. An exce dissolves in the latter salt, and crystallises on cooling in large

Chloride of magnesium forms two double salts, with m $MgCl^2.3HgCl^2.H^2O$, and $MgCl^2.HgCl^2.6H^2O$, both deliquescen gives two compounds, one of which crystallises in tetrahedr salt.

Potassium-salts.—When an aqueous solution of potassium-c 30° with pulverised mercuric chloride, the liquid decanted, a q chloride added equal to that already present, and the solution salt $2KCl.HgCl^2.H^2O$ is deposited in large rhombic prisms. If at 30° be left to evaporate without further addition of chloride salt $KCl.HgCl^2.H^2O$ is obtained in delicate asbestos-like cryst tion of potassium-chloride heated to 60° and saturated with merc on cooling to a mass of slender needles having the composition

The *sodium-salt* $NaCl.HgCl^2.2H^2O$ crystallises in six-sided p

The *zinc-salt* has not been analysed. An aqueous solution of ing excess of mercuric chloride deposits the latter, on evaporat crystals, after which a double salt slowly separates in very de needles. (Bonsdorff.)

Mercuric Chloride with Acid Chromate of Ammonium.—A solu these two salts yields, by concentration and cooling, large, shini sided prisms, of the salt $HgCl^2.[(NH^4)^2CrO^4.CrO^3].H^2O$ (Ri Chem. Soc. Qu. J. iii. 202). The salt was discovered by Darb 24), who however assigned to it a different formula. Accordin

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x. 17) the crystals are monoclinic and exhibit the faces oP . . [P∞] . [½P∞] . ∞P . [∞P2] . +P . +½P. Ratio of axes 62 : 1. Angle of b and c = 84° 3′; ∞P : ∞P in the clino- ion = 76° 42′; oP : ∞P = 98° 41′; oP : [P∞ = 117° 6′; oP : avage parallel to oP and −½P∞.

om which this salt has separated, yields by further evaporation of the salt, $HgCl^2.3[(NH^4)^2CrO^4.CrO^3]$. (Richmond and

so forms double salts with the neutral and acid chromates $gCl^2.K^2CrO^4$ and $HgCl^2.K^2CrO^4.CrO^3$]. See Chromates (i.

ith Basic Cupric Acetate. $\left.\begin{matrix}(C^2H^3O)^2\\ Cu''^2\end{matrix}\right\} O^5.2Hg''Cl^2$. This com-

rding to Wöhler, on mixing the solutions of mercuric chloride ite, saturated at ordinary temperatures, and leaving the mixture : it then separates in radiate hemispheric groups of crystals blue colour. It is nearly insoluble in cold water, and is de- ter.

lso unites with *sulphide of ethyl*, forming the compound y described (ii. 545); and with *sulphide of methyl*, forming a

ANIDE OF. See Cyanides (ii. 253).

ECTION AND ESTIMATION OF. 1. *Reactions in* mercury compounds are decomposed by heat, and give off me- curous chloride and bromide and mercuric chloride and iodide . All mercury-compounds, when thoroughly dried, intimately *ate of sodium*, and heated before the blowpipe in a tube closed osed and give off metallic mercury, which condenses in the cold e mercury-compounds which are volatile without decomposition, le, may escape decomposition by carbonate of sodium. In this be slightly moistened with water, the water expelled by gentle and removed with blotting paper, the tube being held horizon- ter from running down to the heated part. When the moisture ypipe flame is applied as before. This is an easy and certain rcury. When the quantity of mercury present is very small, rms on the cold part of the tube may look, to the unassisted eye, y; but examination with a lens will show that it consists of

2. *Reactions in Solution.*

alts. Normal or neutral mercurous salts are white; the basic low. Most of them are soluble in water, redden litmus, have a not act very violently on the animal body. All soluble mercur- lecomposed by water, a basic salt being precipitated and an acid ee acid redissolves the basic salt.

sulphide of ammonium form with mercurous salts a black pre- ulphide Hg^2S, insoluble in sulphide of ammonium and in nitric uriatic acid and in sulphide of potassium.

d *soluble chlorides* form, even in very dilute solutions, a white s chloride, which is insoluble in dilute acids, and is blackened by Boiling nitric acid dissolves it; boiling hydrochloric acid decom- chloride which dissolves, and metallic mercury, which remains

forms a greenish-yellow precipitate of mercurous iodide (always, ercuric iodide) soluble in excess.

n separates metallic mercury, the mercurous cyanide Hg^2Cy^2, stance, being resolved into mercuric cyanide, $HgCy^2$, and mer-

ssium forms a white; ferricyanide of potassium, a reddish-brown

and *oxalic acid* form white precipitates; *chromate of potas-*, a brownish-yellow precipitate.

reduced by metallic *copper* and *zinc*, by *stannous chloride*, *fer- us acid*, and *phosphorous acid*, metallic mercury being separated

are converted into mercuric salts by boiling with *nitric acid*.

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β. Of Mercuric salts. Normal mercuric salts
to 1 at. Hg) are colourless; the basic salts are fr
acrid poisons, and have a disagreeable metallic tast
Most of them are soluble in water. They are parti
paration of a basic salt requiring free acid to disso
solves in water without decomposition; hence a sol
some of its reactions from that of the nitrate and o
composed by water. From their aqueous solutions
precipitated in the metallic state by the same subs
the complete reduction of the mercury is often pre
rous salt: such for example is the action of *phospho*
chloride, metallic *copper*, &c. *Formic acid* reduces
no excess of the reagent carries the reduction fur
nearly to boiling. *Gold* does not by itself reduce
of a mercuric solution be laid on a piece of gold
brought in contact with the moistened surface, an
gold becomes amalgamated at the point of contact.

Sulphydric acid and *alkaline sulphides*, added
down a black precipitate of mercuric sulphide, solu
ever, the quantity of the reagent added is not suffi
white precipitate is formed, consisting of a compo
original salt, and often coloured yellow or brown b
tion is quite peculiar to mercuric salts.

Hydrochloric acid forms no precipitate in solutio

Ammonia and *carbonate of ammonium* form whi
of a mercurammonium salt. The *fixed alkalis* t
mercuric oxide (not hydrated), insoluble in excess.
large quantity of free acid, no precipitate is f
considerable time.

Carbonate of potassium or *sodium* throws do
but if any ammoniacal salt is present in the so
carbonates throw down the white precipitate abo
potassium or *sodium* also gives a brown-red precipita
but with the chloride, it forms a white precipitate
carbonates of barium, strontium, and *calcium* p
solutions of the sulphate and nitrate, but not from

Phosphate of sodium throws down white mercuri
nitrate, but not from the chloride. *Chromate o*
precipitate.

Cyanide of potassium gives with mercuric nitr
excess: it does not precipitate the chloride.

Ferrocyanide of potassium forms, in solutions
which gradually turns blue, prussian blue being
cyanide of mercury. *Ferricyanide of potassium*
nitrate, no precipitate with the chloride.

Tincture of galls forms an orange-yellow precipita
the chloride.

Iodide of potassium produces a scarlet precipi
excess either of the mercuric salt or of iodide of po

3. *Quantitative Esti*

Mercury is generally estimated in the metall
mercuric sulphide HgS, or as mercurous chlo
its compounds in the metallic state, it may be
of hard glass sealed at one end. Into this tube i
nate of calcium, about an inch long; then the mixtu
lastly a layer of quicklime about two inches long, an
in its place. The open end of the tube is next drawn
an obtuse angle. The tube is laid in a combustion
used for organic analysis, the neck being turned do
narrow-mouthed bottle containing water, so as to
the water. The tube is then gradually heated by
round it, beginning at the part near the neck con
portion having been brought to a full red heat, the
the middle part, to decompose the compound and v
of the compound that may volatilise undecomposed
the red-hot lime at the end. Lastly, the back part

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evolve carbonic anhydride and sweep out all the mercury tube. The quantity of carbonic anhydride thus evolved may he carbonate of calcium with acid carbonate of sodium. The the water in the bottle, which must be kept cold. The water ly as possible; the mercury transferred to a weighed porcelain of the water which still adheres to it removed by means of ng completed over sulphuric acid; and the mercury finally

recipitated from its solutions in the metallic state by *stannous s acid* at temperatures above 60°; the solution then decanted; water, and dried in the manner just described.
d with a considerable quantity of organic matter, as in cases the organic matter may be destroyed by treatment with nitro- tory apparatus (i. 365), and the liquid subjected to the action negative pole being composed of a plate of platinum or gold. ts on this plate, and may be estimated by weighing the plate riment.
rcury in the form of mercurous chloride is best effected by *cid* and *formate of potassium or sodium*. If the mercury is e alloy must be dissolved in nitromuriatic acid; if it is con- form of mercuric nitrate, hydrochloric acid must be added, the nearly neutralised with potash, the formate then added, and ne days to a temperature between 60° and 80° (at the boiling be reduced to the metallic state). The mercurous chloride then e collected on a weighed filter, washed, dried at a gentle heat,

t experiments of H. Rose (Pogg. Ann. cx. 529), the best of g mercury is to precipitate it as calomel from the solution of *osphorous acid*, either at ordinary temperatures or at a very rature rises above 60° metallic mercury is precipitated.
ently precipitated from its solutions, as a sulphide, by *sul-* ase, if the precipitate consists of the pure protosulphide, HgS, wn from a solution of corrosive sublimate, the precipitate may weighed filter, washed, dried over the water-bath, weighed, cury thence determined. But if, as is generally the case, the free sulphur, as when it is thrown down from a solution con- considerable excess of nitric acid; or if it be precipitated in phides of other metals, then the mercury must be separated with lime, as above described. Or again, the mixture of ted into chlorides by gentle heating in a stream of chlorine of mercury passed into water, and the mercury precipitated nous chloride.
curous salt present in a solution may also be determined drochloric acid. The solution must, however, be very dilute, t also contain but a very small quantity of free nitric acid, as convert the mercurous into mercuric chloride. To determine rous and mercuric salt, when they exist together in solution, rst precipitated with hydrochloric acid, and the remaining oride or sulphydric acid.
C. W. Hempel (Ann. Ch. Pharm. cx. 176) estimates mercury chloride, by means of a standard solution of iodine in iodide lves it in the form of potassio-mercuric iodide:

$$Hg^2 + 6KI + I^2 = 2(2KI.HgI^2) + 2KCl.$$

sed is estimated by a graduated solution of hyposulphite of quantity of mercury is thence calculated.
by Hempel (Ann. Ch. Pharm. cvii. 98) consists in agitating with dilute sulphuric acid and *permanganate of potassium* till nating the quantity of permanganate used for the purpose by tion of oxalic acid.
in solution as a mercuric salt, it is precipitated as calomel by ny of the other methods above given.

ration of Mercury from other Metals.

ated from all other metals, except arsenic and antimony, by When it exists in the form of an amalgam, the compound is quantity of mercury determined by the loss of weight. If it

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exists as an oxide, chloride, &c., combined with c
separated by distillation with *quicklime*, as above
alkali and earth-metals, and from uranium,
zinc, and chromium, may also be effected by pre
bismuth and cadmium it may be separated b
from copper, by mixing the solution with excess
sulphydric acid through the liquid, whereby the
while the copper remains dissolved; from lead
sulphuric acid, with addition of alcohol (H. Rose
excess, as otherwise a basic sulphate of mercury r
From arsenic, tin and antimony, mercury is s
phides of those metals in sulphide of ammonium.

Field (Chem. Soc. J. xii. 32) separates mercu
precipitated sulphides with moderately strong *h*
sulphide of antimony and leaves the sulphide of r

From silver, mercury, if in the form of a n
hydrochloric acid, which precipitates the silver alo
the form of a mercurous salt, the two metals are p
the separation is then easily effected by *ammon*
silver, and blackens the mercurous chloride; or th
acid, in the cold, which dissolves the chloride of n
undissolved.

When mercury, silver, and lead occur toget
the mercury to the state of mercuric salt by boili
then be precipitated by *hydrochloric*, and the lead
may be effected by *cyanide of potassium*, the solut
an alkaline carbonate, and cyanide of potassiur
nitric acid throws down the whole of the silver
solution as cyanide, and the lead as nitrate, from
by an alkaline carbonate.

For the analysis of a mixture of mercuric
Wöhler recommends the following process: The
which dissolves the mercury as mercuric oxide, and
which dissolves, and dioxide, which remains undi
also left undissolved. The lead is precipitated fr
acid, and then the mercury by sulphydric acid o
then treated on the filter with a mixture of warm
solves out the dioxide of lead, and the residual cinn

The separation of mercury from gold in solut
the gold in the metallic state by warming the so
afterwards adding hydrochloric acid to redissolve
at the same time. If the hydrochloric acid wer
process, it would greatly retard the precipitation
course be in the mercuric state.

5. *Atomic weight of*

The atomic weight of this metal was for many
periments of Sefström, made in 1812 (Schw.
202·52 for Hg″. Turner, however, in 1835 (A
analysis of mercuric oxide and chloride, obtaine
200·3, and his results have been confirmed by
Marchand in 1844 (*ibid.* lii. 216). These chem
and dried mercuric oxide by ignition in a stream
the liberated oxygen (part of which would otherw
ignited charcoal and copper; and collected the
escaping gases being finally freed from mercury b
gold-leaf. In five experiments, in each of whi
oxide, Hg″O, were decomposed, they found fro
cury; mean 92·597 per cent. Hence the value o
mean 200·14. It is usual to take as the true at
or Hg″ = 200.

The vapour-density of mercuric chloride, whic
Mitscherlich, is 9·8, gives a condensation to 1
2 vols. for $HgCl^2$ (p. 897). This result affords a
atomic weight and the diatomicity of mercury in th
presently see that this view is further corroborate
compounds of mercury.

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HIDE OF. See MERCURY-RADICLES, ORGANIC.

UORIDES OF. Mercury forms two fluorides, corresponding in chlorides.

ride. $(Hg^2)''F^2$. Berzelius obtained this compound as a sub-ercurous chloride, by heating the latter with fluoride of sodium. xamined by Finkener (Pogg. Ann. cx. 142), who obtains it by itated calomel to a solution of silver-fluoride (prepared by digest-ith hydrofluoric acid); the whole of the silver is then gradually liquid evaporated over the water-bath, yields small yellow fluoride. An easier mode of preparation is to add recently carbonate to hydrofluoric acid, which dissolves it completely n of carbonic anhydride, but on addition of a larger quantity ioride as a heavy, light yellow, crystalline powder. From a solu-luoric acid it is deposited in indistinct (apparently cubic) crystals. is partly dissolved by water, partly decomposed into mercurous acid. It is blackened even by moist air, especially if exposed ecomposed when heated above 260° in dry air, mercury subliming, becoming corroded. From the solution of the compound in *sh* throws down mercurous oxide; *ammonia*, a black precipitate nercury and quickly turning grey, while the filtered liquid le and soon deposits a white mass containing mercury, ammonia, rcurous fluoride is decomposed in like manner, by the prolonged *onia*, into metallic mercury and a mercuric compound. It slowly turning black and being converted into fluoride of mercuros-".F^2.

oride, $Si^2(Hg^2)''F^6.2H^2O$, is deposited from the solution of mer-drofluosilicic acid, in transparent, colourless, prismatic crystals.

de. $Hg''F^2$. Mercuric oxide added to hydrofluoric acid is con-yellow powder, consisting of an oxyfluoride, and by repeatedly ed with hydrofluoric acid, mercuric fluoride is deposited as a s containing $HgF^2.2H^2O$. The same product is obtained by xide to a large excess of aqueous hydrofluoric acid (containing F) (Finkener, Pogg. Ann. cx. 628). According to Frémy lvii. 5), mercuric fluoride is obtained in long colourless hydrated owever, contaminated with hydromercuric fluoride or mercuric evaporating a solution of mercuric oxide in excess of hydro-; however, did not obtain crystals in this manner.

fluoride decomposes at 50°, giving off hydrofluoric acid together ng the **oxyfluoride**. It is permanent in dry air at ordinary decomposed by *water*, yielding mercuric oxyfluoride and a ric acid containing a small quantity of mercuric oxide. A fluoride in hydrofluoric acid mixed with a slight excess of er some time in the cold, and immediately when heated, a white which, when washed and dried over sulphuric acid, consists of oxyfluoride $2NH^3.Hg^2F^2O$. (Finkener.)

ide and *Silico-oxyfluoride*.—A solution of mercuric oxide in ields by evaporation small pale yellow needles, which were as mercuric silicofluoride; but according to Finkener they fluoride $Hg''Si^{iv}F^6.Hg''O.3H^2O$. This compound is resolved by y temperatures, into a soluble acid salt and an insoluble yellow

ic oxide in hydrofluosilicic acid, concentrated so far that oxy-o separate, and then left to itself at a temperature below 15°, bohedral crystals grouped like steps, probably consisting of silicofluoride $Hg''Si^{iv}F^6.6H^2O$. They are very unstable ightly heated, but effloresce over sulphuric acid. (Finkener.) curic fluoride with *fluoride of ammonium* is produced, according g mercuric fluoride with aqueous ammonia.

IDES OF. Mercury unites with iodine in three or four **mercurous** and **mercuric iodide** analogous to the chlorides, ercuric iodide, and perhaps a **periodide**. The two elements ibination, when large quantities are employed, being attended of temperature.

de. $(Hg^2)''I^2$.—This compound is produced by triturating 127 pts. iodine or 454 pts. mercuric iodide, with addition of a

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little alcohol, and removing any mercuric iodide that or remain unacted upon in the second, by solut mercurous iodide undissolved. It may also be obta salt with iodide of potassium. The acetate is best a once pure mercurous iodide. When the nitrate is contaminated with mercuric iodide, either formed d solution, or by the oxidising action of free nitric acid mercurous iodide.

Mercurous iodide is a greenish-yellow powder of very sparingly soluble in *water*, quite insoluble in *a* tially, leaving a grey residue. Mercurous iodid resolved, under various circumstances, into metallic mercuric iodide. When *heated*, it yields a sublimate mercuric iodide. When treated with *hydriodic acid* or or other metallic iodides, it is resolved into mercury with the other iodide, forming a soluble salt. In t blackened by exposure to *light*.

Mercurous iodide is used in medicine, and in greatest care must be taken to insure its perfect fre is a violent poison. To test its freedom from this adr p. 217) heats it with *aniline*, whereupon, if it conta magenta colour is produced, whereas if the mercur tion takes place.

Mercuroso-mercuric Iodide. Hg^4I^6 = (Hg tating mercurous nitrate with iodide of potassium till it has acquired a yellow colour. According to tion of potassium iodide with ½ at. iodine, in which precipitated at once. The compound may also b iodide with one-third as much mercury as it (Hg^4I^6).

Mercuroso-mercuric iodide is a yellow powder w and may be sublimed without alteration. The sub red colour while hot, but become yellow on cooling (insoluble in *water* and in *alcohol*, the latter not ext It remains unaltered when kept in the dark; but to light. *Hydriodic acid* and solutions of *iodides* mercuric iodide, the latter uniting with the solubl the mercurous iodide itself, as above described, w (Boullay.)

Mercuric Iodide. $Hg''I^2$.—This compound at. mercury with 2 at. iodine (200 pts. mercury to according to Mohr, however, the combination of th complete, the product always containing a certain during the drying over the water-bath, also some by sublimation into mercuric iodide and metallic gramme of alcohol on 100 grammes of mercury, an portions of 10 grms. each, stirring after each ad colourless. After the last 4 grms. of iodine ha permanently coloured, in consequence of the comp mercuric iodide; the product is washed with alc best prepared by precipitating mercuric chloride w iron: α. 8 pts. mercuric chloride and 10 pts. io separate portions of water, the solutions mixed, an and carefully washed. β. 2 at. iodine immersed iodide by addition of iron-turnings; the resulting a solution of 1 at. mercuric chloride ($HgCl^2$), and quickly separated from the liquid, to prevent it basic ferric chloride which is gradually deposited

Mercuric iodide thus obtained is a powder of a soluble in *water*, more soluble in *alcohol*, especially *ether*. It dissolves easily in aqueous *iodide of p* solution in beautiful red quadratic octahedrons, ∞P∞ . oP . P, and ∞P∞ . oP. Length of prin in the terminal edges = 96° 24′; in the latera parallel to oP. Specific gravity = 6·2009 (Ka (Schiff).—The red iodide turns yellow when ge perature, and sublimes in bright yellow rhombic

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the angle ∞P : ∞P = 66° (*Kopp's Krystallographie*, pp. 160,
e is therefore dimorphous, and exhibits a red colour in one of its
in the other. The red modification is much more stable than
yellow crystals, even when left to themselves at ordinary tempera-
er their original colour and crystalline structure, being converted
he red crystals; the same change takes place instantly when the
ressed, rubbed, or scratched. The yellow iodide retains its
has been prepared by subjecting the pulverised red iodide to a
ellow crystals obtained by sublimation often turn red on cooling,
friction or agitation resulting from the contraction of the glass
ls themselves (Mitscherlich). Mercuric iodide precipitated
ie chloride by iodide of potassium, is likewise yellow at the first
ı, but quickly turns red, even while immersed in the liquid. In
f the alteration may be easily watched under the microscope—
næ being observed in the first instance, which continually
ming truncated on their edges and angles, and ultimately dis-
uadratic octahedrons appear in their place (Warington). The
iodide in alcohol ether, aqueous iodide of potassium, &c., are
ierefore be supposed to contain the yellow modification; if, how-
ites slowly from them in crystals, these crystals are red; but if
place rapidly, as for example when the alcoholic solution is
iodide is yellow at the first instant of separation, but very soon
to Reynoso (Compt. rend. xxxix. 696), an alcoholic solution
as been kept for some time gives immediately a red precipitate
(Ann. Ch. Pharm. cxi. 371), on the other hand, found that an
ch had been kept for fifteen months, still gave a yellow precipi-
d the yellow crystals which formed in it likewise remained
Schiff also finds that the alcoholic solution, when mixed with
quite milky, and after a few hours deposits shining yellow
ngles of 114° 30′ and 65° 30′, and exhibiting beautiful coloured
rising microscope.

d with mercuric iodide, abstracts the iodine with incandescence.
erted by many of the heavy metals on trituration, either alone or
ng iodide sometimes uniting with the iodide of mercury to form
nd *tin* form amalgams with the liberated mercury. [For the
vidual metals, see *Gmelin's Handbook*, vi. 38.] When mercuric
queous *potash*, mercuric oxide separates, and a yellow solution is
otassio-mercuric iodide, $2KI.3HgI^2$:

$$HgI^2 + 2KHO = HgO + 2KI.3HgI^2 + H^2O,$$

t deposits mercuric oxide, and then greenish-yellow needles of
otash acts in like manner and more easily. *Soda*, *baryta*, and
a similar manner, producing double iodides; *lime*, *carbonate of*
te of sodium do not decompose mercuric iodide when boiled with
ohol be substituted for the water, decomposition takes place, the
avour the action by its solvent power. Mercuric iodide dissolves
te of calcium when the solution is heated; and as it begins to
e of calcium in the form of a white jelly, while mercuric chloride
ammelsberg). When *chlorine gas* is passed into water in
is suspended, a bright yellow solution is formed, containing
trichloride of iodine. (Filhol.)

Mercuric Iodide.—Mercuric iodide unites with the more
es, forming a series of double salts, Bonsdorff's iodohydrar-
been particularly studied by Boullay (Ann. Ch. Phys. [2] xxxiv.
ined, for the most part, by dissolving mercuric iodide in the
e iodide, and evaporating the solution. Mercuric iodide likewise
h metallic chlorides.

Iodide, $(NH^4)^2HgI^4.3H^2O$, or $2NH^4I.HgI^2.3H^2O$, separates in
hot solution of mercuric iodide in iodide of ammonium, after
has been previously deposited. When heated, it melts and
ered, partly decomposed. Water separates mercuric iodide from

ide.—A solution of mercuric iodide in aqueous iodide of barium,
n excess of mercuric iodide by cooling and dilution, depos ts
le in water, which, according to Boullay, have probably the
. A hot saturated solution of mercuric iodide in iodide of barium
portion of the mercuric iodide, and the mother-liquid yields by

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evaporation, crystals apparently consisting of BaI
decompose when dried at a high temperature, or wh
water, mercuric iodide separating. (Boullay.)

Cadmio-mercuric Iodide is obtained by tritura
mercuric iodide, and exhausting with water. Crys
very soluble laminæ. (Berthemot.)

Calcio-mercuric Iodide. $CaI^2.2HgI^2$?—Obtained
and decomposed in a similar manner by water.

Ferroso-mercuric Iodide.—The saturated solution
yields, by evaporation over sulphuric acid, yellow-br
in contact with the air (v. Bonsdorff). A hot s
yields, after deposition of a portion of the merc
deliquescent needles, which are decomposed by wat
acid and by alcohol. (Berthemot.)

Magnesio-mercuric Iodide.—A hot saturated solut
magnesium, deposits mercuric iodide on cooling;
greenish-yellow, needle-shaped crystals, which pro
are resolved by water into mercuric iodide, and
$MgI^2.HgI^2$. (Boullay.)

Potassio-mercuric Iodide.—A concentrated solutio
at the boiling heat, 3 at. HgI^2 to 2 at. KI; and of
deposited on cooling, while the mother-liquor depos
in long yellow prisms. The crystals, when heated,
to a red liquid, from which mercuric iodide separa
and in ether, but water decomposes them, separati
and the liquid then yields by evaporation a saline
$2KI.HgI^2$ (Boullay). Dilute acids decompose th
iodide. Potassio-mercuric iodide is likewise easily
potassium-iodide with mercuric oxide.

Sodio-mercuric Iodide.—Iodide of sodium reacts
manner to iodide of potassium. The solution, afte
yields by evaporation, a yellow, non-crystallising m
or scratched, from separation of mercuric iodide.

Strontio-mercuric Iodide, prepared like the corres
yellowish needles.

Zinco-mercuric Iodide, prepared by Bonsdorff, cry
cent, rhombic prisms.

Periodide of Mercury, HgI^4? is obtained, ac
aqueous mercuric chloride with a solution of pot
with iodine. It forms a purple-red powder, which
and free iodine by heating or by exposure to the air
of mercuric iodide with io ne.

MERCURY, IODOCHLORIDE OF.—$Hg^{II}{}^3I^2$
on dissolving mercuric iodide in a hot solution of
on cooling in white, jagged, fern-like laminæ (Lieb
saturated solution of mercuric iodide in corrosive su
powder, $Hg^{II}Cl$; a less saturated solution yield
yellow crystals, which, as well as the powder, soon tu
iodide.

MERCURY, IODOSULPHIDE OF. See M

MERCURY, MERCAPTIDE OF. Syn. wi
Ethyl, Sulphydrate of (ii. 548).

MERCURY, METHIDE OF. See Mercury

MERCURY, NITRIDE OF. $Hg^{II}{}^3N^2$. See T
bases, Ammoniacal (p. 917).

MERCURY, OXIDES OF. Mercury unites
forming the mercurous and mercuric oxides,
chlorides.

Mercurous Oxide. Hg^2O. *Black oxide of*
suboxide of mercury). It is produced by treating
tion of a mercurous salt, with excess of caustic alk
position, it must be washed and dried in the
divided calomel in water, treats it at once with exce

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e mercurous oxide thus obtained yields but few globules of but if too little potash be added in the first instance, there is onovan, a mercurous oxychloride; and on further addition of rcurous oxide, mercuric oxide and metallic mercury. According . Phys. [2] i. 422], it is impossible to obtain this oxide pure, g, even in the dark, it is partly resolved into a mixture of tallic mercury. The product formed by triturating mercuric nerely a mixture.

brown-black powder, destitute of taste and smell. The specific ed from calomel by the action of caustic potash is 8·9503 rapath). It is very unstable, being resolved, even on exposure by slight trituration in a mortar, into mercuric oxide and t a *red heat*, it is resolved into mercury and oxygen-gas. *orous acid*, it yields mercury and phosphoric acid. By at about the melting points of those metals, it is decomposed, l slight detonation, yielding metallic mercury and an alkali. ck with *phosphorus*. It is slowly decomposed by *phosphoretted* m). When boiled with aqueous *iodide of potassium*, it yields, otassio-mercuric iodide; if the mercurous oxide is in excess med at the same time (Berthemot, J. Pharm. xiv. 189). A f *sal-ammoniac* decomposes it in a similar manner, ammonia cury being separated, together with mercuric chloride (Pagen- rm. xxvii. 27; L. Thompson, Phil. Mag. [3] x. 179). *Car-* ikewise decomposes mercurous oxide into mercuric oxide and

—Mercurous oxide dissolves in acids, forming the mercurous e produced by dissolving mercury, under particular conditions, ds, such as nitric or sulphuric acid; also in some cases by pre-

us salts have the composition $(Hg^2)''A^2$, $(Hg^2)''A''$, $(Hg^2)'(A'')^2$ enoting an *n*-atomic acid or chlorous radicle, such as $\dot{N}O^3$, $\ddot{S}O^4$,

Mercurous nitrate = $(Hg^2)''(NO^3)^2$
Mercurous sulphate = $(Hg^2)''(SO^4)''$.

e regarded as compounds of mercurous oxide with anhydrides, nitrate, as $Hg^2O.N^2O^5$.

mercurous salts, which may be regarded either as compounds of nercurous oxide, or as oxy-salts, analogous to the oxychlorides d on the type of two or more molecules of water, in which more n is replaced by mercury, *e.g.*,

$$Hg^2O.Hg^2(NO^3)^2 = (Hg^2)^2\left\{\begin{matrix}(NO^3)^2\\O\end{matrix}\right. = \left.\begin{matrix}(NO^2)^2\\(Hg^2)^2\end{matrix}\right\}O^2.$$

$$2Hg^2O.Hg^2(NO^3)^2 = (Hg^2)^3\left\{\begin{matrix}(NO^3)^2\\O^2\end{matrix}\right. = \left.\begin{matrix}(NO^2)^2\\(Hg^2)^3\end{matrix}\right\}O^1.$$

nd reactions of mercurous salts see p. 899.

HgO. *Red oxide of mercury* (also called *bioxide* and *deutoxide* ide was known to the Arabians in the eighth century. Geber nd Lullius showed how to prepare it by igniting mercury-nitrate; e end of the seventeenth century, discovered that it may be ercury in contact with the air.

keeping mercury for a month or longer at a boiling heat in a nd having a long loosely-fitting tube adapted to its mouth: the called in pharmacy, *Mercurius præcipitatus per se*.—2. By ex- rcurous nitrate to a high and gradually increasing temperature r, in a glass vessel surrounded with sand, as long as nitrous save nitric acid, the nitrate, moistened with water, may be vith an equal weight of mercury, till the latter is completely ration is called *Mercurius præcipitatus ruber*. Care must be temperature too high. The oxide prepared by this process on l powder; in commerce, it occurs in shining crystalline grains. ac, the small unpulverised crystals of mercurous nitrate yield the le, but the pulverised salt yields the first form. The more perfect oxide prepared on the large scale is undoubtedly due to the the heat increases.—3. By precipitating a dissolved mercuric ash, and washing the precipitate.

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Impurities and Adulterations.—1. *Basic mercuric* sufficiently heated. The oxide containing this salt gi heated in a retort. It may be purified in this manne by washing with water.—2. *Nitre.* May be com —3. *Minium.* Remains in the form of fused pro oxide is strongly heated in a glass tube, or in when the mercuric oxide is dissolved in nitric behind, when the oxide is ignited or dissolved in nit when the oxide is dissolved in hydrochloric acid.

Properties.—Pure mercuric oxide is generally cry and of a bright brick-red colour; by pulverisation i lighter as the powder is finer. When prepared on t lent, earthy mass or powder, of a brownish brick precipitating a mercuric salt with an alkali, it for Specific gravity: 11·000 (Pol. Boullay), 11·074 (11·29 at 4° in vacuo (Royer and Dumas), 11·13(heated, it becomes vermillion-red, and afterwards vi colour on cooling. It has a repulsive metallic taste

The precipitated yellow oxide is more readily de than the red oxide obtained by the first or second me by Pelouze (Compt. rend. xvi. 50) to the difference the precipitated oxide being amorphous and the cal Lussac (*ibid.* xvi. 309) has shown that the differen divided state of the precipitated oxide; chlorine act because the smaller surface presented by the lat mercuric chloride, which impedes the further actio varieties of the oxide are subjected to the action o solves the mercuric chloride as fast as it is formed, on the two can be perceived. The yellow as well as

Mercuric oxide is not quite insoluble in water; a 1858, p. 345) 1 pt. of it dissolves in 200,000 pts. of in 125,000 pts. after boiling and cooling of the li metallic taste; turns violet juice green; becomes shining films of metallic mercury; is turned brown ammonia. (Guibourt, Donovan.)

Decompositions.—Mercuric oxide gradually turns being superficially decomposed into oxygen and Guibourt, or, according to Donovan, into oxygen an it volatilises completely, being resolved into oxygen of the mercurial vapour again takes up oxygen, and the surface of the mercury which passes over, a *phosphorus*, mercuric oxide detonates under the h and water, it yields phosphide of mercury and aque at ordinary temperatures, the same mixture yiel oxide, no phosphoric or phosphorous acid dissolving Siqueira). A phosphate is likewise formed at the *phosphorous acid* forms mercury and aqueous ph Siqueira). Mercuric oxide mixed with *sulphur*, tremendous explosion (Proust). Concentrated oxide, immediately converts it into fluid mercury, At ordinary temperatures, smaller quantities of s temperature amounting to 7·5°, and form a white sulphate, part of which dissolves in the liquid. An this powder grey, and reduces it very slowly, but co long as this change remains incomplete, the liquid rendered turbid by addition of common salt; neverth sulphide of ammonium, and after long standing, or metallic mercury in the form of a grey powder; th complete, provided the quantity of sulphurous ac *Potassium* or *sodium* heated to the melting point, vivid combustion and slight detonation, yielding me Lussac and Thénard.) *Zinc* and *tin* filings, and mercuric oxide, likewise occasion fiery decompositio poured upon mercuric oxide reduces it to the metalli stannic chloride, part of which is precipitated in the f attended with a rise of temperature amounting to 60 *oxide* converts mercuric into mercurous oxide; so l

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Heated solution of *sugar* reduces mercuric to mercurous oxide
gas decomposes mercuric oxide at a red heat, the products
mercuric chloride; at lower temperatures, hypochlorous acid
are formed. The latter sometimes combines with the excess of
oxychloride.

With Ammonia.—Thénard's *fulminating mercury*, see MERCURY, p. 918.

This compound is obtained, according to Berthollet, by boiling
ide and water, separating the solution from the undissolved por-
ide liquid to the crystallising point. It then separates in yellow

.—These salts are formed by dissolving mercuric oxide in acids;
idising acids aided by heat on metallic mercury; also with
on boiling various ammonium-salts with mercuric oxide. The
presented by the formula Hg^nA_m or $(Hg'')^n(A^n)^2$, the symbol A^n
id or chlorous radicle, *e.g.*:

ate . . . . . $Hg''(NO^3)^2 = \left.\begin{matrix}(NO^2)^2\\ Hg''\end{matrix}\right\}O^2$

hate . . . . . $Hg''(SO^4)'' = \left.\begin{matrix}(SO^2)''\\ Hg''\end{matrix}\right\}O^2$

phate . . . . . $Hg''^3(PO^4)^2 = \left.\begin{matrix}(PO)^2\\ Hg''^3\end{matrix}\right\}O^6$.

be represented by formulæ similar to those of the basic mer-

$Hg''O.Hg''(NO^3)^2 = Hg''^2\left\{\begin{matrix}(NO^3)^2\\ O\end{matrix}\right. = \left.\begin{matrix}(NO^3)^2\\ Hg''^2\end{matrix}\right\}O^3$.

$2Hg''O.Hg''(NO^3)^2 = Hg''^3\left\{\begin{matrix}(NO^3)^2\\ O^2\end{matrix}\right. = \left.\begin{matrix}Hg''^3\\ (NO^2)^2\end{matrix}\right\}O^4$

$2Hg''O.Hg''(SO^4)'' = Hg''^3\left\{\begin{matrix}(SO^4)''\\ O^2\end{matrix}\right. = \left.\begin{matrix}Hg''^3\\ (SO^2)''\end{matrix}\right\}O^4$.

s are, for the most part, colourless; the basic salts yellow:
etallic taste, and are violent acrid poisons. They are decom-
y at the boiling heat, with separation, generally of a basic salt,
ric oxide, as from the nitrate, the solution retaining sometimes
ometimes a free acid. Hence H. Rose (Pogg. Ann. cvii. 298),
as the weakest of all basic oxides, no other oxide being preci-
ns of its salts by water. In the solution of mercuric chloride,
tate, either of oxide or basic salt, the oxide being precipitated
y strong bases, since mercury, like the other noble metals, has a
orine than for oxygen. Conversely, mercuric oxide precipitates
lutions of their chlorides, but not of their oxygen-salts. Those
ed to a solution of mercuric chloride, do not form a precipitate
loride, are thrown down by mercuric oxide from their solutions
ereas those which precipitate mercuric oxide from the solution of
wn down by that oxide from the solutions of their own chlorides.
s are not precipitated from their solutions in hydrochloric acid
m solution of *manganous chloride*, the manganese is completely
time, as manganous oxide (manganous sulphate, on the other
). From solution of *chloride of lead*, mercuric oxide throws
m *chloride of zinc*, the red-brown oxychloride (sulphate and
ecomposed by it). From the *chlorides of nickel* and *cobalt* it
les of those metals, the former completely, the latter for the
s are not decomposed). From *ferrous chloride*, ferrous oxide
uric oxide immediately turning black, but becoming red again
l contains mercuric chloride, if the quantity of mercuric oxide
to form an oxychloride; and the insoluble residue consists
nd a ferric oxychloride, produced by the reaction, $2Hg''O + (Fe^2)^{vi}O^2Cl^2$. From *ferric chloride*, mercuric oxide in excess
on as ferric oxide, forming an insoluble mercuric oxychloride
te is not altered by it). From *cupric chloride* it throws
cupric oxide; cupric sulphate is decomposed by it after a long
oxide being converted at the same time into a solid lump of
and basic cupric sulphate. (H. Rose.)

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MERCURY, OXYBROMIDE OF. *Basic* $3Hg''O.Hg''Br^2$.—This compound is obtained, acco oxide and bromide together in water, or by boilin quantity of potash not sufficient to precipitate it a yellow crystalline powder, and crystallises fr needles. Rammelsberg obtained it, as a dark-brow bromide with carbonate of sodium.—Mercuric oxy what soluble in hot *water*, easily soluble in *abso* aqueous alcohol (Rammelsberg). It is resolved sublimate of mercury, mercurous and mercuric b oxide (Löwig). By boiling *potash*, it is conver mercuric oxide; whereas, according to Rammelsber dissolves mercuric oxide from it, and leaves the br

MERCURY, OXYCHLORIDE OF. Mer several proportions, and the compounds may be o action of mercuric oxide on a solution of the chlor the latter solution with caustic alkalis or alkaline c of chlorine on mercuric oxide. According to Millon 2, 3, or 4 at. mercuric oxide; but it is difficult to several compounds. The usual mode of preparing ric chloride saturated at 15°, with a solution of pe ($KHCO^3$) saturated at the same temperature. A pr at once obtained; whereas if a neutral alkaline ca tated:

α. $H\ddot{g}^3Cl^2O^2 = Hg''Cl^2.2Hg''O$, is obtained by monopotassic carbonate with 6 to 10 pts. of the so and immediately collecting the precipitate in a filt powder containing yellow mercuric oxide, which When 1 pt. of the solution of the acid potassium- mercuric solution, the liquid being well stirred and precipitate is first formed, which gradually turns re acquires a tinge of purple-red, and ultimately of vi position as the preceding. When 1 pt. of the pot the mercuric solution, and the liquid is briskly sti begin to form on the side of the vessel; and if the mixture prepared, and briskly stirred, a dark preci gradually passes into shining black. It has the but when treated with potash, it yields red mercu

β. $H\ddot{g}^4Cl^2O^3 = HgCl^2.3Hg''O$. Obtained on mi and leaving the mixture at rest. The liquid the shining, golden-yellow, crystalline scales, from whi oxide.

γ. $Hg^5Cl^2O^4 = H\ddot{g}Cl^2.4Hg''O$.—When 4 to 6 mixed with 1 pt. of the mercuric solution, no precip while, carbonic anhydride is given off, and a brow position above given, forms on the surface of th gradually deposited from all the liquids filtered fr is likewise obtained by imperfect precipitation of a Potash separates the red oxide from it. All the ot this compound when treated with boiling water, th shining crystalline scales, also consisting of the s yellow modification of the oxide. The same co Thaulow, when chlorine gas is passed into water pended; the analysis of the compound thus prod with the formula of the tetrabasic chloride. (*Hand*

When a solution of mercuric chloride is boile with it, and then left to itself for a considerable be formed. A solution of mercuric chloride boiled a mixture of the several oxychlorides; and on de cooled to 60°, it yields small rhombic crystal $2HgCl^2.HgO$, which may be freed from admix alcohol. (Roucher.)

According to Roucher's latest experiments (J Jahresb. 1849, p. 283), the composition of the ox mercuric chloride on mercuric oxide, is different,

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oxide is used in its preparation, and likewise varies with the tem-
ature of the solvent. At high temperatures, whether the red or
e oxide be employed, and whether the chloride be used in the state
holic solution, the products formed are invariably the same, viz. a
npound, $HgCl^2.2HgO$, containing the red oxide, and a white,
ubstance, consisting of $2HgCl^2.HgO$. At ordinary temperatures,
lways produces the yellow compound $HgCl^2.3HgO$. The red
e cold with excess of corrosive sublimate, dissolved either in water
black $HgCl^2.2HgO$; but when the oxide is in excess, and the
the state of aqueous solution and frequently renewed, a more
es place, and the compound formed is $HgCl^2.6HgO.H^2O$; by
ar manner, but using a somewhat larger quantity of the chloride
e anhydrous compound $HgCl^2.6HgO$ is produced. Finally, the
t is influenced by trituration: for, by triturating the red oxide in
n of corrosive sublimate renewed at short intervals, the product
ined.

xychlorides yield, when heated, a sublimate of mercuric chloride,
posed into oxygen, mercurous and mercuric chlorides, and a residue

KYCYANIDE OF. See CYANIDES (ii. 255).

KYFLUORIDE OF. See p. 903.

KYGEN-SALTS OF. For the general characters of these
0; and for the special descriptions, see the several Acids.

XY-IODIDE OF. *Basic mercuric iodide.* $Hg^4I^2O^3$ =
ompound is obtained by melting the oxide and iodide together
ortions, or by heating the iodide with dilute potash-ley. It is a
der, mostly mixed with excess of oxide. [For its reactions with
URY-BASES, AMMONIACAL, p. 919.]

IOSPHIDE OF. This compound is formed:—1. By heating
ry with $1\frac{1}{2}$ pt. phosphorus (Pelletier); 2. By digesting 2 pts. of
$1\frac{1}{2}$ phosphorus and 1 water, mercuric phosphate being formed at
etier); 3. By decomposing heated calomel with vapour of phos-
; 4. By boiling aqueous mercuric chloride with phosphorus
he decomposition of aqueous mercurous nitrate by phosphoretted
nson); 6. When phosphoretted hydrogen gas is passed over dry,
curic chloride, whereupon the phosphide of mercury sublimes.

cury (1 and 2) is black; may be cut with a knife; gives off, when
osphorus, and afterwards the mercury; and, when exposed to the
its phosphorus by oxidation. That prepared by method (3) is
rown-red (Berzelius); according to Davy, it remains solid at
mercury, and may be preserved unaltered. That prepared by (5)
k-brown flakes. The preparation (6) is an orange-yellow subli-
mewhat suddenly heated, is resolved into phosphorus and mercury.
n. xxiv. 335.)

HOSPHOCHLORIDES OF. — *α.* $Hg^6P^2Cl^6.3H^2O = Hg^3P^2$.
rmed by passing phosphoretted hydrogen-gas through an aqueous
n of mercuric chloride. It is a yellow powder, which, when
ields a large quantity of hydrochloric acid-gas, 77·59 per cent.
d a residue of phosphoric acid. By boiling with *water*, it yields
l a solution of hydrochloric and phosphorous acids free from mer-
h decomposes it in a similar manner. Heated with dilute *nitric*
nitric oxide, and is converted into 86·77 per cent. of calomel.
n. xl. 75.)

$HgCl^2.2PCl^5$.—Obtained by direct combination of pentachloride
ercuric chloride. It forms easily-fusible needles, which volatilise
ecompose when suddenly heated. (Baudrimont, Compt. rend.

ELENIDE OF. *Mercuric Selenide*, $Hg''Se$, may be produced
union of its elements at a high temperature. As thus prepared, it
ss, which, when strongly heated, sublimes without previous fusion
ing laminæ. It obstinately resists the action of the greater num-
is dissolved by *nitromuriatic acid*, as mercuric selenite. *Nitric*
ne oxidation, but only after long-continued boiling.

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Selenides of mercury occur at Zorge and at Till
Clausthal. Their composition is exhibited in the follo

	Tilkerode. Schulz.	*Zorge.* Marx.
Mercury . .	74·02	74·5
Selenium . .	23·61	25·5
Sulphur . .	0·70	
	98·33	100·0

The Tilkerode mineral contains also a trace of copper
blowpipe, the greater part volatilises, leaving 11·85 per c
10·85 per cent. ferric oxide). The preceding analysis
If the loss be reckoned as selenium, the mineral ha
$Hg''Se$. The analyses of the minerals from Zorge a

formula Hg^6Se^3, which is that of a mercuroso-mercu
$4Hg''Se$. It is possible however that these minerals
curic selenide $Hg''Se$ (Rammelsberg's *Mineralchemi*

The native selenides of mercury are massive minerals
and no cleavage. Hardness = 2·5. Specific gravity =
ore). Lustre metallic. Streak shining. Colour steel

Selenide of Mercury and Lead forms the mineral *Leh*
(pp. 558, 570).

Selenide of Mercury, Lead, and Copper.—Minerals
at Tilkerode and at Zorge in the Harz; they are intimat
grey mineral crystallised in small cubes, and a violet
Two specimens analysed in Rammelsberg's laboratory

	Se.	Pb.
a. (Specific gravity 5·74)	38·53	25·36
b. („ „ 4·86)	34·19	43·05

MERCURY, SELENIO-SULPHIDE OF. *O*
with other ores of mercury near San Onofre in Mex
H. Rose's analysis (Pogg. Ann. xlvi. 315), 6·49 per ce
81·33 mercury; whence it appears to be a compound, or p
of 1 at. HgSe and 4 at. HgS. In its physical cha
selenide.

Del Rio (Pogg. Ann. xiv. 182) mentioned a grey mi
containing 49 per cent. selenium, 1·5 sulphur, 24 zinc
mineral likewise containing selenium, mercury, and zin
526), he described the latter as a mixture of selenio-s
cadmium, selenide of iron, and free selenium.

MERCURY, SULPHIDES OF. Mercury form
the oxides.

Mercurous Sulphide. Hg^2S.—This is the bla
phydric acid or sulphide of ammonium in solutions o
prepared by passing sulphydric acid gas through a soluti
nitrate is used, the liberated nitric acid exerts an oxid
The best mode of preparation, according to Berzelius,
mercurous nitrate into a dilute solution of sulphydrate
a solution of either of these sulphydrates may be poure
pitated and still moist.

Mercurous sulphide in the dry state is a deep-blac
gentle heat into mercuric sulphide and metallic mercu
the sulphide in the form of small globules. At a stro
first of metallic mercury, afterwards of cinnabar.

Mercuric Sulphide. $Hg''S$. This compound ex
stallised; in the former state it is black; in the latter,
constitutes the well-known pigment called cinnabar o

a. Amorphous Mercuric Sulphide.—When mer
together for a long time in the proportion 100 mercury
form black mercuric sulphide; the product thus obt
Aethiops mineralis.—The same compound is formed by
pt. sulphur; but the product thus obtained is of rather
the volatilisation of a portion of the sulphur; moreover i
tity of cinnabar, which remains undissolved on b-ilin
...iops is wholly or almost wholly soluble in that qu

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precipitating the solution of a mercuric salt with excess of sulphy-
sulphide; by agitating mercury with pentasulphide of ammonium
exposing cinnabar to a very gentle heat in a close vessel.

uric sulphide is a velvet-black powder or a greyish-black mass
hat strongly in a close vessel, it yields a sublimate of cinnabar;
ontact with the *air*, the sulphur burns and the mercury volatilises;
ustic alkalis or *alkaline carbonates*, it gives off all its mercury and
lkaline sulphide (liver of sulphur). It withstands the action of
ecomposed, with separation of sulphur, by very strong *nitric acid*;
scarcely any action upon it; *nitromuriatic* acid dissolves it with
t is likewise soluble in aqueous *sulphide of potassium*, and the
evaporation to a mass of slender colourless needles consisting of
c sulphide, $K^2Hg''S^2.5H^2O$, which is decomposed by water, with
nercuric sulphide.

mercuric sulphide. Cinnabar, Vermillion. Cinnabar occurs
the most important ore of mercury: its principal localities have
ated (p. 883). By far the greater part of the vermillion occurring
ver prepared by sublimation of the amorphous sulphide.

eparation.—1. *In the dry way.*—Mercury, mercuric oxide, or
sublimed with sulphur, yields cinnabar. When 5 or 6 parts of
1 part of melting sulphur, and the mixture is heated, with constant
hur becomes thick, combination takes place suddenly, attended
t and heat, and with violent crackling and projection of the mass.
und exhibits a blackish-red colour, and frequently a distinct red
garded as cinnabar partly mixed with black sulphide of mercury,
mbined mercury and sulphur in a state of minute division. Now,
ict, after being pounded, is mixed with a small quantity of sulphur,
f filled with it is loosely closed with a charcoal stopper, sunk to
oth in sand, and exposed for some hours to a red heat in a slow-
e, a sublimate of pure cinnabar is obtained. The excess of sulphur,
han the cinnabar, escapes; foreign metals remain in the form of
om of the flask. If the upper part of the flask becomes too hot,
abar may be lost by volatilisation.

paration in Amsterdam.—170 pounds of mercury are gradually
f melted sulphur contained in a cast-iron pot, the materials being
n spatula, but not so rapidly as to give rise to active combustion
red out upon an iron plate, and broken into pieces after cooling—
e put into hand-jars capable of holding 1½ pounds of water. The
earthern cylinders 4 feet high, glazed within, and closed at the
k to two-thirds of their depth in a furnace in which their lower
ess. A few hand-jars full of the mixture are thrown into each of
els, and the contents left to crackle and burn till the greater part
lphur volatilises, and the flame diminishes. The smooth, level
ed with a thick, smooth plate of cast-iron; the plate removed as
uantity of cinnabar has collected upon it; the cinnabar which has
r part of the vessel is pushed down again; a fresh plate put on,
ts of the cylinder are stirred up from time to time, and fresh
l. The cinnabar, after being detached from the plates, is ground
vith rain-water.

ation in Idria.—A number of casks, each containing 8 pounds of
42 pounds of mercury, are made to turn upon their axes for two
he contents are converted, with slight evolution of heat, into a
pounds of this powder are then introduced into an upright cast-
sly heated in a furnace; the cylinder is covered with an iron capital,
till the crackling of the mass is over; and the iron capital is then
one-ware, having its beak connected with a tube and receiver, and
The best cinnabar collects in the capital, which is afterwards
t which condenses in the tube and receiver, if mixed with excess
o the quantity introduced at the next sublimation. The cinnabar,
und with water, is well boiled with potash-ley, and washed with
d water. (Mitscherlich, *Lehrbuch.*)

1 part of sulphur and 4 parts of mercury are sublimed in an
ich an iron cover, kept constantly moist, is luted; the fire is kept
y hours; the vessel broken up after cooling; the less pure subli-
purer portion pounded up; the powder sifted into a large vessel
water, with the scum floating on it, is poured off after a while,

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the process being twice repeated; and lastly, the se
(*N. Edinb. J. of Sc.* ii. 352.)

European cinnabar, whether prepared in the dry o
tinge of yellow; the Chinese, which is six times as
although no foreign matter can be detected in it, exce
limation of common cinnabar with 1 per cent. of sul
grey cinnabar is obtained, which becomes brown-red
finely ground, and repeatedly boiled with solution of l
washed and digested with hydrochloric acid, and a
becomes exactly like the Chinese vermillion, but of a
can be detected in it. (Wehrle, *Zeitschr. phys. v. W*

The principal point to be attended to in the prepara
is that no black amorphous sulphide shall get mixed w

2. *In the wet way.*—The black, amorphous sulph
action of sulphydric acid, or of alkaline sulphydrates
oxides, and salts, is converted by contact with alkali
cold, but quickly when heated, into the red sulphide.

Very fine cinnabar may be obtained by immersin
precipitate" (p. 916) in a solution of sulphydrate of a
ammonium previously saturated with sulphur: the bl
first acquires passes, at a temperature between 40° an
the beautiful deep red of Chinese vermillion, the chan
the liquid is more concentrated. The colour may be
quent digestion with potash at a gentle heat. (Liebig,

Brunner (Pogg. Ann. xv. 593) carefully triturates
of flowers of sulphur, till the whole is converted int
process which requires three hours for small quantities,
amounts to a few pounds—and heats it in a porcelain
solution of 25 pts. of potassium-hydrate in 133 to 150
perature uniformly at 45°, and never letting it rise ab
continually stirred with the pestle, afterwards from t
evaporates is replaced, so as not to allow the mixtur
jelly. When the reddening has once begun, which ge
hours, the heat must not be allowed to rise above 45°;
tained its greatest degree of brightness, the vessel is
which is better, the mixture is kept for some hours ex
then washed, and the mercury which remains meta
whereupon it yields from 109 to 110 per cent. of cin
finest native variety, and far superior to that obtain
mentioned proportion of the ingredients gives the larg
of mercury yield with 40 pts. of sulphur and 40 of po
with 28·3 sulphur and 51 potassium-hydrate, 94·2;
potassium-hydrate, 81·5; and with 30 sulphur and
cinnabar. (Brunner.)

Döbereiner (Schw. J. lxi. 380) gently heats mercur
of potassium, triturating it continually, till the mercu
powder, a change which generally takes place in abou
decants the liquid (which contains protosulphide of p
sulphur may be rendered fit for another preparation
powder with a small quantity of dilute potash-ley at 4
red colour.

If the cinnabar has become brown from being hea
potash-ley, it may be restored to the state of the fine
water and the application of a moderate heat. (Stor

Th. Martius (Kastn. Arch. x. 497) places the ingred
and packs them into a box, which is fastened to the up
or 36 hours, at ordinary temperatures, the most beauti
afterwards washed and dried. This method not only h
with the labour of trituration, but likewise prevents th
of the cinnabar into the brown state, which is so liable
of heat.

Adulterations.—*Brickdust* remains behind on ignitio
may also be dissolved out by hydrochloric acid.—*Red*
in the form of a fused protoxide, and yields chloride of
on boiling the substance with hydrochloric acid; the
extracted by boiling water.—*Dragon's Blood:* Empyre
of heat; gives a red colour to alcohol.

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e cinnabar and many of the artificial varieties form hemihedral the hexagonal system, the primary form being an acute rhombo- length of the principal axis is 2·29, and R : R in the terminal most ordinary combination is R . oR, somewhat like *fig.* 361 ∞R, the latter sometimes predominating. Cleavage parallel to ined by sublimation assumes the form of fibrous masses. Specific mineral, 8·0 to 8·1; of a cleavable variety from Neumarktel, ly sublimed compound, 8·0602 (Karsten), 8·124 (Pol. Boullay). ive mineral = 2 to 2·5. It is sectile and has a subconchoidal the mass it is cochineal-coloured, transparent, and has an ada- powder is scarlet. It becomes brownish when gently heated; and black at a higher temperature; but if the heat has not been e it to volatilise, it recovers its fine scarlet colour on cooling.

hide contains 86·2 per cent. mercury and 13·2 sulphur; native nost part, nearly pure, the percentage of mercury varying from nt.

tions cinnabar, both natural and artificial, resembles the amor- ting that it is still less easily attacked by solvents. Heated *ny*, and several other metals, it yields metallic mercury and a metal. *Caustic alkalis* and *alkaline carbonates* also liberate the t, while a mixture of metallic sulphide and sulphate remains *ne*:

$$HgS + 4CaO = Hg^{4} + 3CaS + CaSO^{4}.$$

e of lead, it gives off sulphurous anhydride and mercury, leaving d, and a fused slag, which, if the oxide of lead is not in very undecomposed cinnabar.

ULPHOBROMIDE OF. $H''g^{3}Br^{2}S^{2}$, $Hg''Br^{2}.2HgS$. When passed through a solution of mercuric bromide, a white precipi- consisting of this compound, which is afterwards transformed by acid into black mercuric sulphide. The sulphobromide is also the black sulphide with the aqueous solution of the bromide. when dry; splits up into mercuric bromide and cinnabar when by alkalis, but less quickly than the corresponding chlorine-com- decomposed nor dissolved by nitric or sulphuric acid at the

ULPHOCHLORIDE OF. $H''g^{3}Cl^{2}S^{2}$. Produced by reactions e described for the sulphobromide, which it resembles in its pro- f its reactions. Heated in a current of chlorine gas, it yields id mercuric chloride.

ULPHO-IODIDE OF. $H''g^{2}I^{2}S = Hg''I^{2}.Hg''S$. Produced like nd, which it resembles.

SES, AMMONIACAL. (C. G. Mitscherlich, Pogg. Ann. ane, Ann. Ch. Phys. [2] lxxii. 215.—Plantamour, Ann. Ch. mmelsberg, Pogg. Ann. lv. 248.—Millon, Ann. Ch. Phys. [3] *Ueber die Einwirkung des Quicksilberoxyds auf das Ammoniak rbindungen*, Leipzig, 1852; *abstr.* Ann. Ch. Pharm. lxxxiv. 258. . Chem. lxxv. 129; Jahresb. 1858, p. 204.)—By the action of s on mercury-compounds, a variety of substances are formed, some lly regarded as compounds of ammonia with mercury-salts; *e.g.*, *oride* $NH^{3}.Hg''Cl^{2}$; *ammonio-mercurous chloride*, $2NH^{3}.(Hg^{2})''Cl^{2}$; *ide*, $2NH^{3}.Hg''I^{2}$, &c. Kane, in accordance with his amidogen se compounds as containing *amide of mercury*, $NH^{2}Hg'$, com- rcury- or amidogen-compounds. Hirzel and others have repre- ning *nitride of mercury*, $N^{2}(Hg'')^{3}$, as a proximate constituent. ted that they contain ammonia-molecules, in which the hydrogen ced by mercury; and this view has been further developed, in ammonium-theory, these compounds being supposed to contain in which the hydrogen is wholly or partly replaced by mer- n of 100 or 200 pts. mercury to 1 pt. hydrogen, according as the from a mercuric or a mercurous salt, thus:

onium	$N^{2}H^{6}Hg''$
monium	$N^{2}H^{6}(Hg^{2})''$
monium	$N^{2}H^{4}Hg''^{2}$

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Dimercurosammonium .

Trimercurammonium .

Trimercurosammonium .

Tetramercurammonium

None of the mercurammoniums ha

curamine, Hg^2N^2, is produced by
oxide.

Mercurammonium. $\left.\begin{matrix}Hg'' \\ H^6\end{matrix}\right\}N^2$.

ϵ or η,* p. 921) is produced by m
ammonia gas, the salt then takin
extracts bromide of ammonium from
gives off ammonia when treated wit
caustic potash.

Bromide of Mercury and Mer

$HgBr^2$, or *Bromide of Hydrogen and*

HBr, (β), is produced by saturatin
white powder insoluble in water and
resolved by heat into nitrogen, amm
sublimate of mercuric bromide.

Chloride of Mercurammoniu

precipitate. Obtained by precipita
(*alembroth salt*, p. 808) with potash
chloride into a boiling solution of sal-
resulting precipitate redissolves; it
(Mitscherlich). At a gentle heat
$NH^3.Hg''Cl^2$, (γ), which is also formed
ammonia gas, or by distilling mercu

Iodide.—$2NH^3.HgI^2 = \left.\begin{matrix}Hg'' \\ H^6\end{matrix}\right\}N^2I^2$,
and forms this white compound, whi
ammonia and is reconverted into red

The compound $NH^3.Hg''I^2$ (δ) is ob
ammonia, as a white crystalline pow
a brown powder consisting of hydrat
ing the ammoniacal solution, the con
gives off its ammonia when exposed
and by acids. (Caillot and Corri

Dimercurammonium. $\left.\begin{matrix}Hg''^2 \\ H^4\end{matrix}\right\}$
(α or ζ), known in pharmacy as inf
tatus albus, is formed by adding am
first produced it is bulky and milk-w
washing with cold water, it turns

of tetramercurammonium, $Hg''^4N^2Cl^2$
especially distinguished from calome
alter white precipitate, whereas calo
pound as an *amidochloride of mercur*

The tetrammonium salts (p. 918),
compounds of dimercurammonium

$Hg''^4N^2Cl^2.2H^2O$ as $Hg''^2H^4N^2Cl^2.2Hg$
salt produced by the action of ammo

as a sulphate of tetramercurammoni

sulphate of dimercurammonium, (Hg''

* The Greek letters in this and the f

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of ammonium and dimercurammonium $\left.\begin{matrix}Hg''^2H^4N^2\\2H^4N\end{matrix}\right\}S^2O^8.2H^2O$, (*ν*),

g mercuric oxide by small portions to a cold saturated solu-
nmonium, waiting each time for the last portion to dissolve,
to show turbidity, from separation of a white basic compound.
on to evaporate at ordinary temperatures (if evaporated over
ain deposits a white basic compound), the double salt crystal-
ll white needles, or more definite colourless rhombic crystals,
ater at 115°. The salt dissolves easily in sulphate or chloride
n hydrochloric acid, either dilute or concentrated, and in very
tric acid, but is insoluble in strong nitric acid, and is completely
sulphuric acid at the boiling heat.
completely decomposed by water, even in the cold, and converted

arthy powder, consisting of the basic salt, $2(Hg''^2H^4N^2)SO^4.3Hg''O$,
parates, when a solution of sulphate of ammonium, saturated with
ured into water. It resembles the sulphate of tetramercur-
cal turpethum) above mentioned. The latter is also produced by
urated double salt with water, continually renewed as long as
uric acid.
pound is obtained by dissolving the above-described double salt in
acid, and adding the solution to an excess of dilute potash-ley;
n off, and a white substance separates, which, when washed with

15°, has the composition $Hg''^2H^4N^2SO^4.3Hg''O$, or $(Hg''^4N^2)SO^4$.

last described compound, or of the double salt, in hydrochloric
dilute potash-ley, kept constantly in excess, forms a white pre-

$^2)Cl^2.3Hg''O$ or $(Hg''^4N^2)Cl^2Hg''O.2H^2O$, (*β'*). This compound
queous chloride of ammonium, giving off ammonia, and forming a
monium and dimercurammonium, which however has not yet been
lly, by boiling the last-mentioned compound with strong potash-ley
from white to yellow, another oxychloride is obtained, having the

$N^2)Cl^2.4Hg''O$ or $Hg''^4N^2Cl^2.2Hg''O.2H^2O$, (*α'*), and by con-
ay with fresh portions of potash-ley, more and more chlorine and
moved, till at last nothing is left but pure mercuric oxide.

e. Hg''^3N^2. This compound is formed by passing dry ammonia
mercuric oxide previously well washed and dried:

$$3HgO + 2NH^3 = Hg^3N^2 + 3H^2O.$$

being removed by nitric acid, the trimercuramine is obtained in
a-brown powder, which explodes by heat, friction, percussion, or
riol, almost as violently as iodide of nitrogen. When cautiously
of potassium, it is decomposed without detonation, yielding am-
ned mercury. It is also decomposed by hydrochloric, sulphuric
ric acid, yielding an ammoniacal and a mercuric salt. (Planta-
rm. xl. 115.)
arious ammonia-salts at a boiling heat on mercuric oxide, com-
which may be regarded as compounds of trimercuramine with mer-

h phosphate of ammonium, the salt $Hg''^3N^2.Hg^3P^2O^8.2H^2O$ (*μ*);
compound $Hg''^3N^2.C^4H^6Hg''O^4.4H^2O$ (λ) (Hirzel). These com-
egarded as salts of tetramercurammonium (p. 918).

onium. $\left.\begin{matrix}Hg''^3\\H^2\end{matrix}\right\}N^2$. The only known salt of this base is the

$^3)^2.2H^2O$, (*ρ*), which is produced as a white precipitate on
very acid solution of mercuric nitrate with very dilute ammonia.
garded as a *basic nitrate of mercurammonium*, $\left.\begin{matrix}Hg''\\H^6\end{matrix}\right\}N^2.(NO^3)^2$.
g to Mitscherlich, as a *basic ammonio-nitrate of mercury*,

monium. Hg''^1N^2. By acting on mercuric oxide with aqueous
mpound is obtained, the so-called **mercuramine** which may

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be regarded as a hydrated oxide of t

strong base and forms definite salt
decomposition, at ordinary temperat

curammonium combined with mer
salts represented by corresponding
oxide with the chloride, iodide, acet
formulated as compounds of mer
tetrammonium salts are also produ
oxide (Hirzel, lxxxiv. 258), and in

Acetate of Tetramercuramm
compound obtained by treating me
dried at 100° it leaves a yellowish-

The *arsenate* is a white salt, ol
ammonium.

Bromate. $(H\ddot{g}^4N^2)Br^2O^6.2H^2O$,
lution of mercuric bromate slightly s
remaining in solution. When heate
detonates with great violence, metal
berg.)

Carbonate. $(H\ddot{g}^4N^2)CO^3.4H^2O$ (
water, in which hydrate of tetram
powder, which may be washed wi
Hirzel, by boiling finely-divided me
obtained a salt having the same c
yellowish-white when dry, turned g
potash, but gave off all its nitrogen
sulphide of potassium. By treating
carbonate of ammonium, Hirzel

$(H\ddot{g}^4N^2)CO^3.H^2O$ (π); when expose
colour.

Millon's carbonate of tetramercur
composition. When perfectly dry, i
higher temperatures it gives off a c
a slight brown tint, not however giv
the heat be raised to 180–200°, mor
of ammonia; the residue has a deep
of carbonic acid, but does not efferv
strong hydrochloric acid, which elim

Chloride. $H\ddot{g}^4N^2Cl^2.2H^2O$ (ω)
ammonium (infusible white precip
better by boiling it with water:

$$2H\ddot{g}^2H^4N^2Cl$$

also by treating the chloride of di
heavy granular, yellow powder, whic
niac. (Kane.)

Chromate. $(H\ddot{g}^4N^2)CrO^4.2H^2O$,
not act on mercuric oxide in the c
compound of chromate of tetram
(Hg^xCrO^4), which when boiled with
off all its nitrogen in the form of an
verted into a lemon-yellow chromate
above indicated.

Hydrate. $\left.\begin{matrix}H\ddot{g}^4N^2\\H^2\end{matrix}\right\}O^2$, (θ).—Thi
curic oxide with aqueous ammonia,
a caustic alkali. Yellow mercuric
on by ammonia; the red modificatio
monia on the latter retains the cryst
the hydrate obtained by either proc
paper, and drying it over oil of vitr

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btained as a brown powder containing $\left.\begin{matrix}Hg''^{4}N^{2}\\H^{2}\end{matrix}\right\}O^{2}.H^{2}O$, (*o*). By
ime under a bell-jar it is obtained as a yellow substance containing

. The product prepared from the yellow oxide parts with its water
han that obtained from the red oxide.

compound $\left.\begin{matrix}Hg''^{4}N^{2}\\H^{2}\end{matrix}\right\}O^{2}.H^{2}O$ (the so-called *anhydrous mercuramine*),
represented as a compound of oxide of dimercurammonium with
$H^{4}N^{2}O.2Hg''O$, or as a hydoramine (i. 197) containing $\left.\begin{matrix}Hg''^{4}\\H^{4}\end{matrix}\right\}N^{2}O^{3}$, is
ct with the air. The yellow more highly hydrated compound, on the
carbonic acid rapidly from the air and turns white, being converted
etramercurammonium. It is insoluble in *water* and in *alcohol*,
hen boiled with *potash*, but requires long boiling to complete the
e brown compound is decomposed by fusion with *hydrate of*
gen, metallic mercury, and mercuric oxide.
ercurammonium dissolves very easily in *acids*, forming the salts of
expels ammonia very readily from its salts, like lime. It dissolves
isk evolution of ammonia gas, in a hot solution of *nitrate of am-*
ution deposits, on cooling, a considerable quantity of white crystals,
ed by water, yielding a greenish-yellow powder. It dissolves also
n a hot solution of *sal-ammoniac*, with evolution of ammonia, and
e powder insoluble in water.
esting mercuric iodate with ammonia, Millon obtained a salt of
n which decomposed at about 180°, with detonation and formation

$^{2}.2H^{2}O$, (*ω*).- -This compound may be formed in several ways.—
uric iodide with excess of ammonia:

$$I^{2} + 8H^{3}N + 2H^{2}O = Hg''^{4}N^{2}I^{2}.2H^{2}O + 6H^{4}NI.$$

and dimercurammonium is formed at the same time and dissolves
hile the iodide of tetramercurammonium remains in the form of a
obtain it pure, the liquid must be decanted before it begins to de-
he brown residue again boiled several times with fresh ammonia,
r no longer deposits crystals on cooling.—2. By passing ammonia-
xy-iodide:

$$Hg''^{4}I^{2}O^{3} + 2H^{3}N = Hg''^{4}N^{2}I^{2}.2H^{2}O + H^{2}O.$$

chloride of tetramercurammonium in aqueous iodide of potassium
adding ammonia to a solution of iodide of mercury and potassium
potash (Nessler, Chem. Gaz. 1856, pp. 445, 463):

$$+ 2H^{3}N + 6KHO = Hg''^{4}N^{2}I^{2}.2H^{2}O + 14KI + 4H^{2}O.$$

ffords an extremely delicate test for ammonia. A solution of iodide
assium is prepared by adding iodide of potassium to a solution of
till a portion only of the resulting red precipitate is redissolved,
nixing the filtrate with caustic potash. The liquid thus obtained
ecipitate with a very small quantity of ammonia, either free or in
moniacal salt. The precipitate is soluble in excess of iodide of
ler.)
rcurammonium is a powder of a brown colour inclining to purple-
small quantity of water at 128°, and if more strongly heated out of
, it melts to a dark brown liquid, and is then decomposed with a
ent explosion, yielding water, metallic mercury, mercuric iodide,
gen, without leaving any residue. Heated with aqueous *sulphide*
off all its nitrogen in the form of ammonia. In a stream of *hydro-*
urns yellow in parts, gives off white fumes, and at a higher tempe-
imate of ammonio-mercuric iod'de, mercuric chloride, chloride of
ide of ammonium. It dissolves easily in warm *hydrochloric acid*,
liquid, which, when concentrated, deposits on cooling red crystals
and yellow crystals of mercuric iodochloride.

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Nitrate. $H''g^4N^2(NO^3)^2.2H^2O$, (like *ι*).—Obtaine of mercuric nitrate with a slight excess of ammonia, a when heated, turns yellow, gives off nitrogen and finally oxygen and mercury. It is altered by boilin *chloric acid*, and is separated from the solution b without decomposition in *nitric* and *sulphuric acids* partially precipitated from the solution by water. (

A yellow crystalline double salt consisting of *nitr*

ammonium, $\left.\begin{matrix} H''g^4N^2 \\ 2H^4N \end{matrix}\right\}(NO^3)^4.2H^2O$ (*ξ*), is obtained, acc nitrate of trimercurammonium (p. 917) with excess ammonium, which dissolves a portion of the salt. monia evaporates, the double salt separates in cryst

Oxalate. $C^2(H''g^4N^2)O^4.2H^2O$, (*τ*).—Obtained b excess of ammonia and washing the product till the line reaction (Millon); or by digesting mercuric ammonium (Hirzel). It is a white, loose, amorph heated.

Phosphate. $\left.\begin{matrix} (H''g^4N^2) \\ H''g^2 \end{matrix}\right\}P^2O^8.2H^2O$, (*μ*).—Obtained boiling solution of tri-ammonic phosphate. It is a by potash, but gives off ammonia when treated wit (Hirzel.)

Sulphate. $(H''g^4N^2)SO^4.2H^2O$, (*σ*).—*Ammoniac* tained by Fourcroy, and subsequently analysed by mercuric sulphate in ammonia and precipitating th takes up a very large quantity of mercuric sulphat solution is left to evaporate in the air or over oil of with crystalline crusts, consisting of small, hard, hig turpethum (Millon). The salt may also be ob digesting basic mercuric sulphate (*mineral turpethu* the insoluble portion becomes white.

Sulphate of tetramercurammonium is a white h when heated it turns brown and is resolved into wa ammonia, and mercurous sulphate. By sulphydric sulphide and neutral sulphate of ammonium. It nitric acid, very slightly in water.

Some of the basic salts already described as pro phate of ammonium and dimercurammonium, may ammonium-salts (see p. 917).

Mercurous Base

Mercurosammonium. $\left.\begin{matrix} (Hg^2)'' \\ H^6 \end{matrix}\right\}N^2$.—The chloride black substance formed when dry calomel is expos When exposed to the air, it gives off ammonia and

Dimercurosammonium. $\left.\begin{matrix} (Hg^2)^2 \\ H^4 \end{matrix}\right\}N^2$.—The *chloride,* ing calomel in aqueous ammonia, sal-ammoniac bein

$$2Hg^2Cl^2 + 4H^3N = (Hg^2)^2H^4N$$

It is grey when quite dry, and is not altered by boi this compound, regarded it as *mercurous amido-chlo*

Nitrate of Dimercurosammonium. $(Hg^2)'H^4N^2(NO$ is the composition of the velvet-black precipitat *mercury*, which is produced on adding ammonia to According to C. G. Mitscherlich, on the other has the composition $3Hg^2O.N^2O^5.2NH^3$, which is ammonium $(Hg^2)^3H^2N^2(NO^3)^2$.

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the composition and relations of the ammoniacal mercury-
d by the following method of classification, suggested by Mr.
h the greater number of these compounds are represented as
that is, as bodies formed on the mixed type, $\left.\begin{matrix} mH^3N \\ nH^2O \end{matrix}\right\}$, and the

nes, $\left.\begin{matrix} mH^3N \\ nHCl \end{matrix}\right\}$, hydriodamines, &c. This view of the composition
ercuric compounds is exhibited in the following table, in which
ed under the formulæ correspond to those attached to the names
the preceding pages (916–920):

Type $\left.\begin{matrix} mH^3N \\ nHCl \end{matrix}\right\}$

$\left.\begin{matrix} N \\ Cl \end{matrix}\right\}$ ‖ $\left.\begin{matrix} m = 1 \\ n = 2 \end{matrix}\right\}$ $\left.\begin{matrix} Hg'' \\ H^3 \end{matrix}\right\}\begin{matrix} N \\ Br^2 \end{matrix}$ β $\left.\begin{matrix} Hg'' \\ H^3 \end{matrix}\right\}\begin{matrix} N \\ Cl^2 \end{matrix}$ γ $\left.\begin{matrix} Hg'' \\ H^3 \end{matrix}\right\}\begin{matrix} N \\ I^2 \end{matrix}$ δ

$\left.\begin{matrix} Hg'' \\ H^6 \end{matrix}\right\}\begin{matrix} N^2 \\ Cl^2 \end{matrix}$ ε $\left.\begin{matrix} Hg''^2 \\ H^4 \end{matrix}\right\}\begin{matrix} N^2 \\ Cl^2 \end{matrix}$ ζ $\left.\begin{matrix} Hg'' \\ H^6 \end{matrix}\right\}\begin{matrix} N^2 \\ I^2 \end{matrix}$ η

Type $\left.\begin{matrix} mH^3N \\ nH^2O \end{matrix}\right\}$

$\left.\begin{matrix} Hg''^2 \\ H \end{matrix}\right\}\begin{matrix} N \\ O \end{matrix}$ θ

$\left.\begin{matrix} Hg''^2 \\ H^2 \\ (BrO^2)' \end{matrix}\right\}\begin{matrix} N \\ O^2 \end{matrix}$ ‖ $\left.\begin{matrix} m = 1 \\ n = 3 \end{matrix}\right\}$ $\left.\begin{matrix} Hg''^2 \\ H^5 \end{matrix}\right\}\begin{matrix} N \\ O^3 \end{matrix}$ κ $\left.\begin{matrix} Hg''^2 \\ H^4 \\ C^2H^3O \end{matrix}\right\}\begin{matrix} N \\ O^3 \end{matrix}$ λ

$\left.\begin{matrix} Hg''^3 \\ H^2 \\ (PO)''' \end{matrix}\right\}\begin{matrix} N \\ O^4 \end{matrix}$ μ ‖ $\left.\begin{matrix} m = 2 \\ n = 3 \end{matrix}\right\}$ $\left.\begin{matrix} Hg'' \\ H^6 \\ (SO^2)'' \end{matrix}\right\}\begin{matrix} N^2 \\ O^3 \end{matrix}$ ν

$\left.\begin{matrix} Hg''^2 \\ H^6 \\ (NO^2)^2 \end{matrix}\right\}\begin{matrix} N^2 \\ O^3 \end{matrix}$ ξ $\left.\begin{matrix} Hg''^4 \\ H^4 \end{matrix}\right\}\begin{matrix} N^2 \\ O^3 \end{matrix}$ ο $\left.\begin{matrix} Hg''^4 \\ H^2 \\ (CO)'' \end{matrix}\right\}\begin{matrix} N^2 \\ O^3 \end{matrix}$ π

$\left.\begin{matrix} \\ \\ O^2)^2 \end{matrix}\right\}\begin{matrix} N^2 \\ O^4 \end{matrix}$ ρ $\left.\begin{matrix} Hg''^4 \\ H^4 \\ (SO^2)'' \end{matrix}\right\}\begin{matrix} N^2 \\ O^4 \end{matrix}$ σ $\left.\begin{matrix} Hg''^4 \\ H^4 \\ (C^2O^2)'' \end{matrix}\right\}\begin{matrix} N^2 \\ O^4 \end{matrix}$ τ $\left.\begin{matrix} Hg''^4 \\ H^4 \\ (CrO^2)'' \end{matrix}\right\}\begin{matrix} N^2 \\ O^4 \end{matrix}$ υ

$\begin{matrix} N^2 \\ O^5 \end{matrix}$ ‖ $\left.\begin{matrix} m = 2 \\ n = 6 \end{matrix}\right\}$ $\left.\begin{matrix} Hg''^4 \\ H^8 \\ (CO)'' \end{matrix}\right\}\begin{matrix} N^2 \\ O^6 \end{matrix}$ χ ‖ $\left.\begin{matrix} m = 4 \\ n = 7 \end{matrix}\right\}$ $\left.\begin{matrix} Hg''^7 \\ H^8 \\ (SO^2)^2 \end{matrix}\right\}\begin{matrix} N^4 \\ O^7 \end{matrix}$ ψ

Type $\left.\begin{matrix} mH^3N \\ nHCl \\ oH^2O \end{matrix}\right\}$

$\left.\begin{matrix} \\ \\ \end{matrix}\right\}\begin{matrix} N \\ I \\ O \end{matrix}$ ‖ $\left.\begin{matrix} m = 1 \\ n = 1 \\ o = 2 \end{matrix}\right\}$ $\left.\begin{matrix} Hg'^3 \\ H^2 \end{matrix}\right\}\begin{matrix} N \\ Cl \\ O^2 \end{matrix}$ α′ ‖ $\left.\begin{matrix} m = 2 \\ n = 2 \\ o = 3 \end{matrix}\right\}$ $\left.\begin{matrix} Hg'^5 \\ H^4 \end{matrix}\right\}\begin{matrix} N^2 \\ Cl^2 \\ O^3 \end{matrix}$ β′

pounds may be formulated in a similar manner, *e.g.*:

rcurosammonium . . . . . $\left.\begin{matrix} (Hg^2)'' \\ H^6 \end{matrix}\right\}\begin{matrix} N^2 \\ Cl^2 \end{matrix}$

nercurosammonium . . . . . $\left.\begin{matrix} (Hg^2)^2 \\ H^4 \end{matrix}\right\}\begin{matrix} N^2 \\ Cl^2 \end{matrix}$

,, ... $\left.\begin{matrix} (Hg^2)^2 \\ H^6 \\ (NO^2)^2 \end{matrix}\right\}\begin{matrix} N^2 \\ O^3 \end{matrix}$

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MERCURY-RADICLES, ORGANIC. (Fra
lxxxv. 381.—Dünhaupt, Chem. Gaz. 1854, pp. 263
xxxix. 57.—Buckton, Ann. Ch. Pharm. cviii. 103; c
Frankland and Duppa, *ibid.* xvii. 415.)

Mercury unites with alcohol-radicles of the series,
amyl,—also with allyl C^3H^5,—forming compounds in
element. These compounds may, in fact, be regarded a
compounds, such as the chloride, bromide, &c., by subs
either the half or the whole of the chlorine, &c., : thu

Mercuric chloride.	Mercuric chlorethide.
$Hg''\{^{Cl}_{Cl}$	$Hg''\{^{C^2H^5}_{Cl}$

When both atoms of chlorine, &c., are completely r
product is an indifferent compound (a neutral merc
with acids or acid elements. But when only half of
radicle is thus replaced, there results a saline compo
which easily undergoes double decomposition, and in
chlorine ($Hhg''C^2H^5$ for example), plays the part of a

The two kinds of compounds here considered, are
same manner as mercaptan and ethylic sulphide are rel
for example, being the ethylic ether of mercuric chlor
is the ethylic ether of mercaptan.

Mercaptan.	Ethylic sulphide.
$C^2H^5\}$	$C^2H^5\}$
$H\ \}S$	$C^2H^5\}S$

There is, however, this difference between the tw
mercuric chlorethide and its analogues, in which only
on alcohol radicle, the remaining chlorous atom is
chlorous radicle, whereas, in the corresponding sul
hydrogen-atom, being basylous, is most easily replac
elements.

If the mercury in these compounds be regarded as
only mercury and an alcohol-radicle must be repre
HgC^nH^{2n+1}; and those which contain iodine, chlorine, &
with mercuric iodide, chloride, &c.; *e. g.* HgC^2H^5, *mercu*
or $HgC^2H^5.HgI$, *iodide*, or rather *mercuriodide, of merc*
of representation affords a much simpler and more sati

Formation of the Alcoholic Mercury-compounds.—T
by four different processes:—1. By the action of merc
radicle, under the influence either of diffused dayli
bination then takes place, and an iodo-mercuric compo
Strecker):

$$Hg'' + C^nH^{2n+1}I = Hg''\}$$

2. By the action of mercuric chloride on a zinc-com
product being an organo-mercuric compound, contain
radicle, or 1 at. alcohol-radicle and 1 at. chlorine, ac
reagents is in excess (Buckton):

$$Hg''Cl^2 + Zn''(C^nH^{2n+1})^2 = Hg''(C^nH^{2n}$$
$$2Hg''Cl^2 + Zn''(C^nH^{2n+1})^2 = 2\left[Hg''\{^{C^n}_{Cl}\right.$$

3. By the action of mercuric chloride on the organ
3 at. of an alcohol-radicle; thus bismutho-triethide
chloride yields bismutho-dichlorethide and mercuric ch

$$\overline{Bi}(C^2H^5)^3 + 2Hg''Cl^2 = \overline{Bi}(C^2H^5)Cl^2$$

4. By the action of sodium-amalgam on the iodides o
of acetic ether (Frankland and Duppa). The reacti

$$2C^nH^{2n+1}I + Na^2 + Hg'' = Hg''(C$$

The acetic ether appears to take no part in the reacti
quantity at the end of the process. Nevertheless, the
ether (viz. methylic acetate or ethylic formate) is essen
inasmuch as sodium-amalgam does not act on the alco
in contact or heated with them; neither is the react

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n adding a few drops of acetic ether, it takes place imme-
tion of sodium in the amalgam must be very small, not ex-
f mercury. If a solid or semi-solid amalgam is used, the reaction
fferent manner.

best mode of preparing the alcoholic mercury-compounds, yield-
large quantities of the methyl-, ethyl-, and amyl-compounds.
and iodomethide are obtained with tolerable facility by the
entioned; but the corresponding amyl-compound was obtained
quantities barely sufficient for its identification. On the other
ric ethide and methide by the second method, requires the previous
rge quantities of the corresponding zinc-compounds, and the pre-
amylide has never been attempted by a similar process, on account
of preparing zinc-amyl. (Frankland and Duppa.)

ounds containing 2 at. of an alcohol-radicle, are easily converted,
mine, chlorine, or iodine, into compounds containing only 1 at.
e.g.:

$$+ \quad Br^2 \quad = \quad \underset{\text{Mercuric brom-ethide.}}{Hg''(C^2H^5)Br} \quad + \quad \underset{\text{Ethylic bromide.}}{C^2H^5Br}$$

exerted by acids, *e.g.* by hydrobromic acid:

$$+ \quad HBr \quad = \quad \underset{\text{Mercuric brom-ethide.}}{Hg''(C^2H^5)Br} \quad + \quad \underset{\text{Ethylic hydride.}}{C^2H^5.H.}$$

l, in like manner, the products are mercuric sulphatethide,
lic hydride.

action is exerted by certain salts. When, for example, mercuric
ercuric ethide, the latter gives up half its ethyl for half the
r, producing 2 at. mercuric chlorethide:

$$''(C^2H^5)^2 \quad + \quad Hg''Cl^2 \quad = \quad 2Hg''(C^2H^5)Cl.$$

, the mercuric compounds containing only 1 at. of an alcohol-
verted into others containing 2 at. of an alcohol-radicle: thus,
d zinc-ethyl act upon one another in such a manner as to yield
odide of zinc:

$$I \quad + \quad Zn''(C^2H^5)^2 \quad = \quad 2Hg''(C^2H^5)^2 \quad + \quad Zn''I^2.$$

ounds containing 2 at. of an alcohol-radicle are converted into
c-compounds when heated with excess of finely-granulated zinc
uppa, Chem. Soc. J. xvii. 29):

$$^{2n+1})^2 \quad + \quad Zn^2 \quad = \quad Zn''(C^nH^{2n+1})^2 \quad + \quad ZnHg.$$

Allyl-compound.

lylide. $Hg'' \left\{ \begin{matrix} C^3H^5 \\ I \end{matrix} \right.$.—When iodide of allyl is agitated with
stalline mass is formed, from which the mercuric iodallylide may
lcohol or ether. The alcoholic solution deposits it on cooling in
turn yellow when exposed to light, especially on drying. It is
old alcohol, nearly insoluble in water. It sublimes at 100°, in
ic plates, melts at 135°, and solidifies on cooling to a yellow
nore quickly and strongly heated, it decomposes for the most part,
as residue, and giving off a yellow sublimate.

ion is decomposed by nitrate of silver, the whole of the iodine
dide of silver; oxide of silver likewise decomposes it, forming
strongly alkaline solution which, on evaporation, yields a syrupy
s, soluble in water, and forming salts with acids. This product
allyl-hydrate, or hydrate of mercurallyl, $Hg'' \left\{ \begin{matrix} C^3H^5 \\ HO \end{matrix} \right.$. (Zinin,
i. 393.)

le is easily decomposed by hydriodic acid and by iodine. The
epresent respectively the action which takes place in each case:

(1). $HgC^3H^5I + HI = HgI^2 + C^3H^6$
(2). $HgC^3H^5I + II = HgI^2 + C^3H^5I.$

for preparing tritylene, by means of iodide of allyl, mercury, and
pends on the first of these reactions. (Linnemann, Ann. Ch.

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Amyl-compounds.

Mercuric Amylide. $Hg''\{^{C^5H^{11}}_{C^5H^{11}}$.—This compo

sodium-amalgam on iodide of amyl, in presence of a
amylic iodide, and 1 pt. acetic ether are agitated wi
externally cooled; the product is distilled over a w
ether, and a current of steam then passed into the r
liquid has distilled over. The residual liquid, after
over chloride of calcium, consists of pure mercuric am

This compound is a colourless, transparent, mobile
at 0°. It has a very faint amylic odour, and leaves a
resembling that produced by other organo-mercurial
tilled, even in vacuo, without partial decomposition.
140°, but long before its boiling point is reached, me
siderable quantity. It may, however, be distilled wit
It is insoluble in *water*, and very slightly soluble in
ether. Exposed to the *air* it suffers no oxidation,
chlorine, it immediately produces dense white fum
Brought into contact with solid *iodine*, it hisses like r
The reaction with *bromine* is still more violent. (Fra

Mercuric Chloramylide, $Hg''\{^{C^5H^{11}}_{Cl}$, is re

curic amylide with alcoholic solution of mercuric chl
sembles the iod-amylide (*vid. inf.*) in its properties,
freely soluble in hot alcohol and ether. From its alc
beautiful hair-like needles, which can be sublimed at
sition. It melts at 86°, and has the appearance of a
colourless. It retains any excess of corrosive sublim
repeated washings with alcohol and water not being
however, be purified by dissolving it repeatedly in a
water. (Frankland and Duppa.)

Mercuric Iodamylide. $Hg''\{^{C^5H^{11}}_{I}$.—An ethe

treated first with alcoholic solution of iodine, and
solidifies to a crystalline mass of mercuric iod-amylic
same time produced:

$$Hg''\{^{C^5H^{11}}_{C^5H^{11}} + I^2 = Hg''\{^{C^5H}_{I}$$

On washing the crude product with weak alcohol, p
paper, and recrystallising from hot alcohol, mercuric io
pearly scales, which are not very soluble in *alcohol*, bu
few drops of alcoholic potash are added to a boiling
these crystals, and the liquid left to cool, no crys
ultimately large pearly plates are deposited, which ha
small scaly crystals above mentioned, and reproduce
and redissolved in alcohol. Mercuric iod-amylide is s
and separates therefrom on cooling in minute crystals
cloud in the liquid. It melts at 122°, and on cooling
mass, having the appearance of stearin; at 140° it b
tion of mercurous iodide. In a moderately heated c
without change. It is but partially decomposed by
zinc to 130° in a sealed tube it yields zinc-amyl an
and Duppa.)

Ethyl-compounds.

Strecker, by acting on iodide of ethyl with m
$Hg''C^2H^5I$, originally designated as *iodide of mercur*
but now called *mercuric iodethide*. Dünhaupt obta
and bromine-compounds, by decomposing bismutho-t
or bromide, and prepared therefrom several of the oth
curic ethide $Hg''(C^2H^5)^2$, by the action of zinc-ethy
mercuric chloride (pp. 921, 922); and lastly Fran
that this compound may be more easily obtained by t
iodide of ethyl, in presence of acetic ether.

Mercuric Bromethide. $Hg''(C^2H^5)Br$.—Obta
bromide on bismutho-triethide, or by treating mercuri

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ic solution of the hydro-ethide with alcoholic bromine. It resembles (Dünhaupt.)

bonethide. *Carbonate of mercurethyl.*—Prepared by decomposing h carbonate of silver at a gentle heat. It crystallises with difficulty mposed by heat. Acids decompose it, with evolution of carbonic haupt.)

orethide. $Hg''(C^2H^5)Cl$.—Obtained by the action of mercuric o-triethide (Dünhaupt); by precipitating the aqueous solution of the oride of sodium (Strecker); and by treating mercuric ethide with f mercuric chloride in excess (Frankland and Duppa). It is *water*, dissolves sparingly in *ether*, and in cold alcohol, but freely and crystallises therefrom in light iridescent laminæ, having a silvery ted to 40° it sublimes in thin laminæ, without previous fusion, but o a clear oily liquid, and then evaporates completely. Heated on rns with a faint flame, diffusing a very unpleasant odour. (Dün-

anethide. $Hg''(C^2H^5)Cy$.—Formed by saturating an alcoholic ic hydrethide with strong hydrocyanic acid. Crystallises readily. en heated in a tube, it emits a vapour which has an extremely ttacks the respiratory organs strongly, and appears to be highly naceous residue is left in the tube. The cyanide dissolves readily in (Dünhaupt.)

hide. $Hg''(C^2H^5)^2$.—This compound is prepared:—1. By the yl on mercuric iodethide. Dry pulverised mercuric iodethide is antities to zinc-ethyl contained in a retort through which a stream ng, the mixture being incorporated by stirring, and, as soon as the ted—which may be known by the stirring rod ceasing to fume on —the product is distilled till nothing but gases pass over. The distil- avy liquid, mixed with a little ether, is then redistilled with a slight , to ensure complete decomposition of the iodethide, then washed with and afterwards with water, and rectified (Buckton).—2. By heating ercuric chloride, avoiding an excess of the latter, as otherwise mer- will be formed: the slight excess of zinc-ethyl is decomposed by parated oxide of zinc dissolved out by dilute hydrochloric acid.

f 16 pts. by weight of iodide of ethyl and 1 pt. of acetic ether is um-amalgam, the flask being alternately agitated to promote the ed into cold water to moderate the rise of temperature. The com- ion is known by the subsidence of the temperature, and the absence s of precipitated iodine, when a few drops of the clear liquid re- sk are boiled with nitric acid. When the quantity of iodide of been increased so far as to render the ethereal liquid pasty, thereby ently intimate contact with the amalgam, it is advisable to place the th, and distil off the more volatile portion of the contents, to be fresh amalgam.* If this distillation be deferred till the residue has hick and pasty, it will not be necessary to repeat it, as the distillate ntly fluid up to the termination of the reaction. The product mixed es into two layers, the ethereal liquid either floating or sinking in n of iodide of sodium, according to the degree of concentration or hen successively treated with alcoholic potash, washed with water, of calcium, and rectified. (Frankland and Duppa.)

vise obtained mercuric ethide by the action of cyanide of potassium

$$^2H^5)I + 2KCy = Hg(C^2H^5)^2 + Hg + Cy^2 + 2KI;$$

reparation is not advantageous, being attended with considerable

is a transparent colourless liquid, having a faint ethereal odour, sparingly soluble in *alcohol*, easily in *ether*. Specific gravity = 2·46. to 160° (Buckton); 159° (Frankland and Duppa). Vapour- 7; calc. (2 vol.) = 9·4.

burns with a smoky flame, giving off a large quantity of mercurial ured into *chlorine gas*, it bursts into flame and is almost entirely violently also with *iodine* or *bromine*, forming mercuric iodethide or action be conducted under water, ethyl, or its products of decom-

* of mercuric amylide (p. 923), this intermediate distillation is not necessary, as ient fluidity to allow the action to complete itself.

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position are eliminated: but if the
ethyl unites with the bromine:

$$Hg(C^2H^5)^2 + I$$

With excess of alcoholic *mercur*
With *hydrochloric* or *sulphuric*
ethide or sulphatethide:

$$2Hg(C^2H^5)^2 + H^2SO$$

Sodium slowly decomposes merc
is very liable to explode from sligh
tact with the air. On applying a
consisting of ethyl and hydride of
first instance, and then decomposed
Heated with excess of finely gra
ethyl and zinc-amalgam. Heated
ethyl, but the decomposition is
ethide to 100°–130°, becomes an
cadmium-ethyl. *Gold* likewise be
metallic compound. Mercuric eth
150°, with *copper*, *iron*, or *silve*
inflammable gas being given off;
heat alone, independently of any
compound is formed in either cas

Mercuric Ethyl-hydrate. H

decomposing a boiling alcoholic so
filtering, distilling off the alcohol
colourless oil, which is strongly
ammonium-salts, but not the salts
with the salts of *aluminium*, *zinc*,
of *sulphydric acid*, it forms a white p
black. With metallic *zinc* it forms z
forming crystallisable salts, viz. me

Mercuric Iodethide. $Hg''($
above-mentioned (pp. 921, 922), or
with a slight excess of alcoholic iod
alchohol and *ether*, and separates
also without decomposition in ca
without decomposition, but requir
posed by direct *sunshine*: hence i
of ethyl, the vessel must be ex
Strecker.)

Mercuric Nitrethide. H

silver added to a solution of the
and a solution of mercuric nitreth
(Strecker.)

Mercuric Phosphatethide,
the chlorethide with phosphate of
evaporation as a viscid diaphanous

Mercuric Sulphatethide.

pared by decomposing the chloret
alcohol in shining laminæ.

Mercuric Sulphethide. H

yellowish-white pulverulent preci
alcoholic solution of the chlorethide
of ammonium, and separates from
always mixed with sulphide of me
by evaporation, depositing sulphide

Me

Mercuric Iodomethide. H
Frankland (Ann. Ch. Pharm. lx

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of methyl in sunshine. In about a week, the liquid solidifies into ine mass, and by treating this mass with ether, the mercuric , and may thus be separated from the remaining metallic mercury ty of iodide of mercury formed at the same time. Very little ing the reaction. Mercuric iodomethide is, however, more easily on of iodine on an alcoholic solution of mercuric methide.

ide is a white solid body, insoluble in *water*, but dissolving pretty *cohol*, more easily in *methylic alcohol*, and very easily in *ether* and By spontaneous evaporation of either of these solutions, the small, nacreous, crystalline laminæ. At ordinary temperatures, it mitting a peculiar and unpleasant odour; the vapour when inhaled aste on the palate which lasts for several days. At 100°, the volatile, the crystals disappearing completely when exposed to a at temperature. At 143°, it melts and sublimes without decom- in extremely thin, shining, crystalline laminæ.

ide. $Hg''(CH^3)^2$. *Mercuromethyl. Hydrargomethyl.* Dis- on (Proc. Roy. Soc. ix. 91), who obtained it by distilling e with cyanide of potassium, hydrate of potassium, or lime. The ined with the cyanide. A mixture of this salt with mercuric ing well triturated in a mortar, is distilled by small portions over oducts are then evolved; iodide of potassium is formed; cyanogen ins in the form of paracyanogen; and mercuric methide passes heavy liquid, which may be purified by washing with water and oride of calcium. The essential part of the reaction is represented

$$I + 2KCy = Hg(CH^3)^2 + 2KI + Hg + Cy^2.$$

pa prepare mercuric methide by the action of sodium-amalgam on presence of acetic ether. The mode of preparation is exactly the y described (p. 925) for the preparation of mercuric ethide, a enser being, however, attached to the neck of the flask, to arrest of methyl, which would otherwise be carried away by the escaping the operation, the residues in the flasks are mixed with water oil-bath, the temperature of which need not be raised above al distillate, after separation from the water which accompanies it, coholic potash to remove acetic ether, and finally purified by

is a colourless, strongly refracting liquid, having a faint and taste. Specific gravity 3·069. Boiling point between 93° and 96°. . = 8·29; calc. = 7·97. It is insoluble in *water*, very soluble *er*, dissolves *phosphorus*, *caoutchouc*, and *resins* easily, *sulphur* in

is very inflammable and burns with a bright flame, giving off It does not unite directly with *oxygen*, *chlorine*, or other electro- out is completely decomposed by them. *Iodine* and *bromine* act etically, eliminating methyl-gas and forming mercuric-, iodo-, or

$$2Hg(CH^3)^2 + I^2 = 2HgCH^3I + (CH^3)^2.$$

ric iodomethide when heated with *mercuric iodide.*

oride it forms a crystalline compound, which is decomposed by on of mercuric chloromethide and a soluble tin-salt. With strong *loric acid*, it acts like mercuric ethide (p. 925), giving off marsh- ystals of mercuric chloromethide or sulphatomethide. With *dilute zinc*, it yields metallic mercury and gaseous products; its salts ide, &c.) are decomposed in like manner (Buckton). Heated alone, it yields zinc-ethyl and zinc-amalgam (Frankland and *ichloride of phosphorus*, it forms mercuric chloromethide.

romethide. $Hg''\begin{cases}CH^3\\NO^3\end{cases}$. *Nitrate of Hydrargomethyl.*—Obtained holic solution of mercuric iodomethide with nitrate of silver, and ltrate in vacuo. Crystallises in nacreous laminæ, containing , very soluble in *water*, sparingly in *alcohol*. At 100°, it melts to which solidifies in a crystalline mass on cooling. Its solution is not *sh* or *baryta-water*. *Hydrochloric acid* and soluble *chlorides* pre- hloromethide in nacreous laminæ. (Strecker, Ann. Ch. Pharm.

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Mercuric Oxymethide, or *Oxide of Hydrargome* ammonia or the fixed alkalis on mercuric iodometh of either of these reagents, and the solutions yi flocculent precipitate of the corresponding *sulphid* and a peculiar and most intolerable odour. (Fran

MEROXENE. Syn. with Biotite. (See Mica

MESACONIC ACID. $C^5H^6O^4$. *Citracartic* lxxvii. 268; Pebal, *ibid.* lxxviii. 129; Baup, *ibi* boiling a weak solution of citraconic acid for half a volume of nitric acid. The reaction takes place deposited in a porcelain-like mass. A certain qua duced at the same time, from which the acid may b charcoal.

Mesaconic acid forms a mass of fine lustrous ne readily so in hot *water*, and also in *alcohol* and in liquid, which solidifies to a crystalline mass. It re bonates. Heated with concentrated *hydriodic aci* and forms pyrotartaric acid; it is also converted With *bromine*, at 60°—80°, it forms mesodibrom (Kekulé, Ann. Ch. Pharm. Suppl. ii. 85.)

Mesaconic acid is dibasic, its salts having the form are almost all crystallisable.

The *neutral barium-salt*, $C^5H^4Ba''O^4.4H^2O$, is ob carbonate of barium. It forms monoclinic prism and give off the greater part of their water of *barium-salt*, $C^{10}H^{10}Ba''O^8.2H^2O$, forms hexagonal persistently retain an excess of acid, from which t *neutral calcium-salt*, $C^5H^4Ca''O^4.H^2O$, forms small pts. of water. The *neutral silver-salt* is a crystalli water. The *acid silver-salt*, $C^5H^5AgO^4$, is obtai neutral salt in solution of mesaconic acid and evap

MESACONIC ETHER. $C^9H^{14}O^4 = C^5H$ a mixture of mesaconic acid, sulphuric acid, and liquid, with an agreeable fruity odour and bitter distils at 220° without alteration. It is not att baryta-water it yields alcohol and mesaconate of ba

MESITE. An oxygenated oil, very mobile, boi of water, said to be obtained by distilling lignone wi and Schweizer.)

MESITENE. Another very mobile oil, boilin water, obtained in like manner.

MESITIC ALCOHOL. A name given to a an alcohol containing the radicle *mesityl*, C^9H^3, isor

MESITIC ALDEHYDE. C^9H^6O. A body together with trinitromesitylene, by heating aceton acid. The action is extremely violent, so that it is as effervescence begins, then heat it again and re When the action is completed, an oil separates, co with trinitromesitylene.

Mesitic aldehyde is lighter than water, has a sw soluble in water, but dissolves instantly in caustic liquid. It absorbs ammonia gas with great avidit which dissolves in water, the solution yielding by *mesitic aldehyde-ammonia*. Nitrate of silver adde forms a yellow precipitate, which blackens when h by the addition of a few drops of potash. (Kane,

MESITIC CHLORAL. Syn. with Dichlorac

MESITIC ETHER. Syn. with Oxide of Me

MESITIN-SPAR. $(Mg;Fe)''CO^3$. *Breun* occurs in rhombohedral crystals isomorphous wit R : R = 107° 23′; oR : R = 136° 52′. Leng Observed planes, R, $-\frac{1}{2}$ R. Cleavage rhomb imbedded. Also massive, granular, and fibrous

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·63. Colourless, whitish, yellowish, and often brown on exposure. anslucent. Brittle. The mineral may be regarded as a mixture carbonates $MmgCO^3$ and $FfeCO^3$, the proportion of the former 42·7 per cent., and that of the latter from 5·1 to 57·2 per cent. contain small quantities of calcium and manganese. Mesitin- e slate at St. Gothard; also in the Zillerthal; at Hall, and else- nd at Traversella in Piedmont. The species includes much of *par.* (Dana, ii. 443.)

hypothetical monatomic radicle, supposed by Kane to exist in $\left.\begin{matrix}C^9H^3\\H\end{matrix}\right\}O$), and in certain products obtained from it.

sityl, C^9H^3Cl, is produced by passing hydrochloric acid into bs it in large quantity; or better by adding 2 pts. of penta- s, by small portions, to 1 pt. of acetone, properly cooled, then separates the chloride of mesityl in the form of an oily liquid It is resolved by heat into hydrochloric acid and mesitylene erts it into oxide of mesityl. (Kane, Pogg. Ann. xliv. 476).

ityl. $\left.\begin{matrix}C^9H^3\\H\end{matrix}\right\}O$. Syn. with Acetone.

tyl. Oily liquid insoluble in water, obtained by distilling nd phosphorus. It has not been analysed. (Kane.)

yl or *Mesitic ether.* $(C^9H^8)^2O$.—Produced: 1. By the action n excess on chloride of mesityl.—2. Together with many other n of strong sulphuric acid on acetone (Kane).—3. By the action Acetone left for several weeks in contact with quicklime, and then l distillation, yields, between 100° and 250°, a mixture of oxide about 129°, and phorone, $C^9H^{14}O$, boiling at 290°, which may y rectification. (Fittig, Ann. Ch. Pharm. cx. 23.)

yl is a colourless oil, smelling like peppermint. Specific gravity g point (corrected) 131°. Vapour-density, obs. = 3·67; calc. 3·39 with a very bright flame (Kane). It is insoluble in *water*, mixes h *alcohol* and *ether*; is converted by *nitric acid* into a brown resi- *horine* into a heavy oil, which appears to have the composition)

osphorous acid.—An acid contained, according to Kane, in the ned by distilling acetone with iodine and phosphorus. This residue o an amaranthine mass, and yields, by saturation with carbonate of ng 20·0 per cent, carbon, 3·8 hydrogen, and 43·8 baryta, whence rmula $PBa'O.C^3H^6O$ (calc. 20·7 carbon, 3·45 hydrogen, and 44·02

oric acid.—An acid produced by treating acetone with phos- ulting liquid neutralised with bases, yields soluble salts. The all rhomboïdal laminæ, which, when exposed to the air, become part of their water. When heated, they melt in their water of ltimately leave a white mass, which, at a higher temperature, burns, leaving phosphate of sodium. The salt was found to con- odic phosphate, and 29·0 water, agreeing approximately with the $O.\frac{5}{2}H^2O$, which requires 49·9 sodic phosphate, and 28·21 water.

uric acids.—Kane found, among the products of the action of cetone, two acids analogous in composition to ethyl-sulphuric acid. mixed with twice its volume of strong sulphuric acid, the liquid umes a dark brown colour, and gives off a large quantity of sul- and if it be mixed after cooling with 2 or 3 volumes of water and t, a deliquescent mass is obtained, in which small prisms may be g, according to Kane's analysis, 70·5 per cent. calcic sulphate, rogen, and 7·9 oxygen, numbers which Kane represents by the ^{4}.

l. acetone with 1 vol. sulphuric acid, and diluting with water when nother acid, the calcium-salt of which was found to contain 23·7 arbon, and 4·4 hydrogen, and may be represented, according to $2C^3H^6O.CaSO^4$.

eral attempts to obtain these acids by the processes above de- btain a trace of either of them; he considers it probable that the the action of oil of vitriol on acetone is methyl-sulphuric acid.

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MESITYLENE or **MESITYLOL.** C^9H^{12}. Hofmann, Chem. Soc. J. ii. 104.—Cahours, Co iii. xvii.)—A hydrocarbon, isomeric with cumene, acid upon acetone. To prepare it, 2 vol. acetone phuric acid, the heat being carefully regulated. the receiver, the upper consisting of very impure sulphurous and acetic acids, resulting from a sec layer is rectified, first over the water-bath to separ over the naked fire. But the product thus obtaine point, and requires to be purified by numerous r distillation over phosphoric acid. (Cahours.)

Mesitylene is a very light, colourless substance, It boils between 155° and 160° (Hofmann), be Vapour-density, obs. = 4·345 to 4·282 (Cahours)

Mesitylene burns with a bright, but very smoky a dark brown liquid which is not altered by exposu *chlorine*, it forms crystalline substitution-products. mesitic aldehyde (Kane). A mixture of *fumi* converts it immediately, and without rise of temp (Cahours). It is likewise decomposed by strong alkalis (Kane). Fuming sulphuric acid converts acid $C^9H^{12}SO^3$. (Cahours.)

Derivatives of Mesit

Tribromomesitylene. $C^9H^9Br^3$.—When bro tylene, waiting each time till the heat evolved has the mesitylene in excess, a white crystalline compo from hydrobromic acid by washing with water, in or three crystallisations from boiling alcohol render needles, which volatilise without decomposition, an potash or ammonia. (Hofmann.)

Trichloromesitylene. $C^9H^9Cl^3$.—To prepar passed through mesitylene till the liquid solidifies dissolved in hot ether and crystallised by cooling, maining in the mother-liquid. The product is p crystals dried between paper, but not in contact wi

It forms white, shining, four-sided prisms, resem ing only at a strong heat, but without decomposi without alteration in dry ammoniacal gas, and are (Kane.)

Nitromesitylene. $C^9H^{11}NO^2$.—Formed by tr acid, not in excess, and carefully cooling the mixtu pound, when treated with an alcoholic solution of pot products on distillation. One of these is a liquid quantity only, and exhibits the properties of an a dissolves very readily in alcohol, and separates fr in very fine tabular crystals; it is isomeric with nit

Dinitromesitylene. $C^9H^{10}(NO^2)^2$.—Obtained rately strong nitric acid. After a few distillations, verted into a crystalline compound, which may be recrystallisation from alcohol. With dilute nitric a the mesitylene being converted, after repeated di shows a tendency to crystallise, but appears to be a

This compound crystallises in fine needles, often ance resembling those of trinitromesitylene (*vid.* position, and dissolves with great facility in alcohol

Nitromesidine. $C^9H^{12}N^2O^2 = C^9H^{12}(NO^2)N$. 116.)—A base obtained by the action of sulphydric

$$C^9H^{10}N^2O^4 + 3H^2S = C^9H^{13}N^2$$

When an alcoholic solution of dinitromesitylene ydric acid, the liquid assumes a dark colour and of sulphur, the odour of the sulphydric acid being treatment is continued for several days, till the su posed. On the addition of hydrochloric acid, sul separating this by filtration, a clear liquid is obtain

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a copious precipitate of impure nitromesidine. By repeatedly dis-
product in hydrochloric acid and reprecipitating by an alkali, small
hering sulphur are separated, and the substance gradually assumes
ur. One or two crystallisations from alcohol now suffice to render

ns long needle-shaped crystals of a golden yellow colour. It melts
difies on cooling in a mass of radiated needles; volatilises without
0°, giving off a vapour which burns with a bluish flame; dis-
n *alcohol* and *ether*, and sparingly in *water*, to which it imparts a
The solutions have an unpleasant bitter taste, and are neutral to

ently on nitromesidine, forming a dark oily liquid. An alcoholic
idine yields with *chlorine*, a pinkish solid substance soluble in

solves readily in *acids*, forming crystalline salts, which however
those yet obtained, excepting the phosphate and the platinum-salt,
mere contact with water. They are soluble in alcohol, and their
id reaction.
$C^9H^{12}N^2O^2.HCl$, forms colourless needles.
te, $2(C^9H^{12}N^2O^2.HCl).PtCl^4$, is precipitated in yellow crystals on
n of platinic chloride in excess, with a saturated solution of hydro-
idine.
unstable, being decomposed, with evolution of red nitrous fumes,
ution is evaporated down to a certain point.
$C^9H^{12}N^2O^2.PH^3O^4$, crystallises in orange-coloured laminæ. When
solved in a very large excess of phosphoric acid, an acid salt is
containing only 1 at. nitromesidine.
s small silky crystals.

lene. $C^9H^9(NO^2)^3$.—Obtained by treating mesitylene with a
itric and sulphuric acids, its formation taking place immediately,
temperature. It is crystalline, and sublimes at a gentle heat in
es. It is very slightly soluble in boiling *alcohol* and *ether*, but
acetone. It is very slowly acted on by *sulphydric acid*, only a
alkaline body being formed after the lapse of several weeks.

-SULPHURIC ACID. *Sulphomesitylic acid.* $C^9H^{12}SO^3$.—This
by dissolving mesitylene in fuming sulphuric acid, the brown
to the air, gradually solidifying to a crystalline mass. When
nate of lead, it forms the *lead-salt* $C^9H^{11}PbSO^3$, very soluble in
, and crystallising in needles when its aqueous solution is left to
er-salt is also crystallisable, very soluble in water and in alcohol,
when exposed to light. (Hofmann.)

ölite.—A zeolitic mineral related to natrolite and scolecite, oc-
globules with a flat-columnar radiate structure. Hardness = 3·5.
35 to 2·4. Lustre silky or pearly. Colour greyish-white, yellowish,
uncoloured. Translucent. Laminæ slightly elastic.
m the Faröe Islands (Berzelius).—*b.* From Annaklef in Schonen
n Bombay (Thomson):

Al^2O^3.	CaO.	Na^2O.	H^2O.		
28·00	11·43	5·63	12·70	=	100·36
27·00	9·00	10·19	11·79	=	100·15
27·50	7·61	7·00	14·71	=	99·52

y be approximately represented by the formula $(2M^2O.SiO^2)$.
, or for the Bombay mineral, $6H^2O$.
now-white mineral, occurring in the amygdaloïd of the north of
pact texture, and very tough, may be included in the same general
s, according to Thomson's analysis, 44·84 per cent. silica, 28·48
5·66 soda, and 10·28 water (= 99·85).

See Scolecite.

See Natrolite and Scolecite.

RIC ACID. Syn. with Inactive Tartaric Acid: see Tar-

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MESOXALIC ACID. $C^3H^2O^5$
298.—Svanberg, Berz. Jahresb. xxv
anic acid is boiled with aqueous alka

$$C^4H^4N^2O^5 + H^2$$
Alloxanic acid.

The acid is obtained by decomposing
by sulphydric acid. It is crystalliss
reaction. It is very soluble in wate
Its aqueous solution, when neutrali
strontium, and calcium, white precip
water.

Mesoxalic acid is dibasic. The *b*
saturated solution of alloxanate of b
carbonate is precipitated, and the sol
urea and mesoxalate of barium, the l
The salt forms yellow laminæ, which
decomposed. Liebig and Wöhler fou
lated percentage is 56·49. The *calc*
2 at. water; at 140° they lose 1 at. w
It is much more soluble than the ba
by dropping aqueous alloxan or alloxa
of lead, appears to be a basic salt, co
heated in the air, pure oxide of lead
of lead. According to Liebig and W
mesoxalic acid to neutral acetate of l
cipitate when mesoxalic acid and am
a basic salt, as it is entirely decompo
silver, perhaps thus, $C^3Ag^2O^5 + Ag$
When mesoxalic acid is compared
the three acids may be regarded as co
CO, oxalyl C^2O^2, and mesoxalyl C^3O^3

Carbonic acid	. .
Oxalic acid	. . .
Mesoxalic acid	. .

The decomposition of oxaluric and al
respectively, shows that alloxanic be
alic does to oxalic acid, and from t
as mesoxaluric acid. A similar re
acid.

MESUA FERREA. This plan
a density of 0·954, a chestnut-brown c
[3] xl. 16.)

METACETAMIDE. Syn. wi

METACETIC ACID. Syn. v

METACETONE. $C^6H^{10}O$?
Ann. Ch. Pharm. lii. 127.)—A substa
tillation of sugar, starch, gum or mar
distillation of lactate of calcium, ar
distillation of wood.

Frémy prepares metacetone by ge
grms. of sugar with 8 times its weigh
the fire after a while, because the wa
with the lime, raises the temperature
further application of external heat.
inflammable gas is evolved, and a co
is shaken up with water to remove
which floats on water, is rectified till
cult, however, to obtain a pure produ
3 pts. lime to 1 pt. sugar, and to kee
the same manner from starch, which
than acetone: gum, on the contrary,

Metacetone is a colourless oil, havi
soluble in *alcohol* and *ether*. Boiling
of Frémy's analyses, 72·2 per cent. c

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as isomeric with oxide of mesityl and oxide of allyl, requires 73·5 gen, and 16·3 oxygen. When distilled with *acid chromate of potash-phuric acid*, it yields carbonic anhydride, acetic acid, and propionic ducts are the same as those obtained by the oxidation of propione, imes regarded as impure propione (Gm. ix. 409). (Pure propione, distillation of propionate of barium, boils at 84° and contains ·8 hydrogen.) Metacetone dropped on heated *potash-lime* or fused *n* distils over in great part unaltered, the residue containing only cid. (Gottlieb.)

IC ACID. Syn. with PROPIONIC ACID.

ITRILE. Syn. with PROPIONITRILE or CYANIDE OF ETHYL

ITE. A foliated columnar mineral from the Büchenberg near Harz. It has a vitreous to pearly lustre and dull leek-green colour. elatinises with acids. Contains, according to List, 23·77 per cent. a, 40·36 ferric oxide, 3·10 magnesia, 0·74 lime, 1·37 potash, 0·08 r (=99·60), whence the formula $3(3M^2O.SiO^2).2(Al^2O^3.SiO^2).10H^2O$ $^2O.2Al^2O^3).8H^2O$. (*Rammelsberg's Mineralchemie*, p. 541.)

IC OXIDE. See CHROMIUM, OXIDES OF (i. 949).

MEIN. See CINNAMEIN (i. 980).

IN. See ACROLEIN (i. 57).

C OXIDE. The modification of ferric hydrate obtained by Péan ing the ordinary yellow hydrate in water (p. 395).

ROL. See FURFUROL (ii. 752).

C ACID. See GALLIC ACID (ii. 760).

ACID. See ULMIC ACID.

ll. Métal. **METALLOÏD.** *Metalloïd. Métalloïde.* The term commonly applied, in technical and popular language, to a number agree in presenting, in various degrees, a combination of certain l characters, by which many of them are easily distinguishable bstances. Gold and silver were formerly regarded as the typical is class of substances. These characters, however, are not by any stinctive of metals; for there are many substances which are not nevertheless possess in a high degree some of the physical cha- At a very early date, attempts made by Basil Valentine (*Con-lsus* (1539), and Boerhave (1732), to adopt a system of classi- separate the more characteristic metals from substances possessing racters, such as zinc, antimony, bismuth, antimony-glance, pyrites were termed semi-metals or bastard metals. In 1735, o make the presence or absence of malleability the principle of this on this ground he separated mercury from the metals. The same by Vogel (1755, *Institutionibus Chemiæ*) and Buffon (1785, *les Minéraux*). Subsequently, when Braune had observed the ury by cold in 1759–60, and this had been confirmed by Hutchins 1783, the malleability of this substance became known, and it was netals.

of the distinction which had been drawn between metals and semi- out by Fourcroy (1789, *Eleméns d'Histoire Naturelle et de Chemie*, dent from the fact that "between the extreme malleability of gold gility of arsenic, other metals presented only imperceptible grada- er, and because there was probably no greater difference between gold and that of lead, which was considered to be a metal, than ead and zinc, which was classed among semi-metals, while in the iate between zinc and arsenic the differences were slight."

etween metals and semi-metals was soon afterwards abandoned, n the existing system of chemistry was established by Lavoisier, mprised seventeen substances. Their chemical relations were nd they were classified together as metals, chiefly on account of sical characters, and because they were regarded as chemically y substances. Since that time a great number of other simple n discovered, which possess more or less the physical characters of o not possess them in that degree which was formerly considered peculiarity of a metal.

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On the discovery of potassium and sodium by
tained as to their metallic nature, and it was propos
on account of their peculiar physical characters, and t
ing only some resemblance to metals (Erman and
xxviii. 121). This proposal was not adopted, and in
metalloïd to distinguish the non-metallic elementa
which sense it has been commonly used up to the
substances which, like the metals, have not been re
and which are consequently regarded as elementary

A high degree of density was long considered to
of metallic substances; but the discovery of the e
that this is not the case, and that, in regard to this,
the term metal has only a relative application, and
senting a class of substances entirely distinct from

This fact has been rendered still more apparent b
chemical characters and relations of metals and oth
substances possessing, in a marked degree, certain
regarded as distinguishing metals, do not possess, in
racters of metals, there are, on the contrary, substa
physical characters of metals, but manifesting in t
tions the most marked analogy with well-defined m
molybdenum, arsenic, titanium, &c., form compoun
are the analogues of sulphuric, phosphoric, nitric, a
hand, the electropositive constituents of the earth
monium, and some of the hydrocarbon radicles, corre
metals, in their general chemical functions, and
compounds which are in the highest degree analog
lead, iron, &c., with oxygen.

In a strictly chemical sense, therefore, the term m
ing an ideal type, to which a number of substances
dently of their physical characters and of their simp

The elementary substances generally regarded
ordinary temperature, the only exception being me
tion of arsenic, they are all capable of becomi
peculiar to each, and some of them are capable of
In the solid and compact state they are in a high d
of metal is absolutely opaque; but very thin lamin
to penetrate through them, as for instance gold-le
colour. (Faraday, see pp. 636, 642.)

In consequence of this impermeability by light a
power of metals in the compact or liquid states,
brilliancy, which may be developed by polishing th
metals is a peculiar grey, with a varying tint of blu
as gold and copper, brass, bronze, &c. (see Light
due to an unequal power of absorption for different
angle which the incident rays form with the surfac
is very small, the whole of the rays are reflected, a

One of the characters which, in combination
been regarded as most distinctive of metallic sub
virtue of which the shape of a mass of metal may
or by other mechanical means, without disintegrati
character, which is presented in various degrees
expressed by the terms *malleability*—denoting the
out under the hammer, or between rollers—and *d*
becoming longer and thinner by drawing through a
section of the piece of metal.

For individual metallic substances, the degree
by no means equal; many metals, which are in a
lead, cannot be drawn into very fine wire, while
iron, copper, gold, possess far greater ductility.
influenced by temperature. Within certain limits
than at low temperatures. The mechanical workin
an alteration in its molecular condition, attended
ductility (*hammer-hardened; écroui*). In such ca
to the metal by heating it and allowing it to cool sl

* From μέταλλον, metal and εἶδ

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so little malleability or ductility that they cannot be rolled into wire.

esistance to forces which tend to tear asunder, either by tension, ng, is another character which metals possess in very unequal ately connected with molecular condition, and is in some way y and ductility. It is largely influenced in particular metals by nce of certain admixtures; by the manner in which they have pe, and by temperature. In general it is reduced by increase of ome cases it is increased within a certain limited range of tem- se of iron (see COHESION, i. 1078). Some metals possess but a tenacity, and are then termed brittle—as zinc, antimony, and

capability of a bar of metal to recover its original shape and ng bent or stretched, is also a character connected with tenacity . It varies much in different metals.

differ very widely in the degree of *hardness* they possess, or are by sudden cooling or otherwise. Some are so soft as to admit of wax (potassium and sodium), others are capable of scratching nd (steel, chromium). The presence of small amounts of various rbon, silicon, &c., in metals, often communicates to them con- As a general rule, a metal is more brittle in proportion to its

of assuming a *crystalline structure*, generally belonging to the some other form of the regular system; antimony and arsenic hedrons. Metals occurring native are frequently crystallised. The e structure in a metal, considerably influences its tenacity. It is d by an increased degree of brittleness, and those metals which tallised are, as a general rule, the most brittle. Crystalline s assumed by metals, while in the solid state, under the influence t, of percussion or of vibration, and other mechanical actions, and uced is often of importance in relation to technical applications 7). Metals may often be crystallised by slowly cooling them in a ien partly solidified, pouring off the remaining liquid metal (see AD, iii. 478). Metals often assume a crystalline structure when solutions of their saline compounds, and some can be crystallised arsenic).

oïds in general present a marked difference in their power of con- d heat; the conductivity of metals for electricity is greater than stances. It varies considerably in different metals, and to some ual metals, according to their molecular condition, temperature, bsence of foreign admixtures.* The purer and softer the metal, ctivity: the higher the temperature of the metal, the less its con- ctivity of some metalloïds is increased by elevation of temperature. *Lehre vom Galvanismus und Electromagnetismus*, i. 180.— , Proc. Roy. Soc. xi. 516.)

oïds differ in their electrical relations, the former being, as a class, latter electro-negative. The distinction, however, is only one of present similar differences among each other. (See ELECTRICITY,

y in their capacity for heat. The specific heat of sodium amounts t of bismuth, lead, mercury, or gold. The conductivity for heat hough metals generally possess a comparatively high degree of . (See Despretz, Compt. rend. xxxv. 540.—Wiedemann and h. Phys. xli. 107.)

ble presents some of the principal physical characters of the tary metals and metalloïds, so far as they have been deter- es the numbers given are only approximative. It must also be existence of these characters, and the degrees in which they are ar substances, are sometimes due to the molecular condition of the n to any inherent peculiarity. This is more especially known to metalloïds, several of which are polymorphic, as sulphur, phospho- licon, &c. (See DIMORPHISM, ii. 331.)

the accompanying table are taken from Matthiessen's experiments (Phil. Mag. [4] xiii. 81). The letters *h*, *p*, and *s* prefixed to the numbers in column were *hard-drawn*, *pressed*, or *soft*.

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Discovered by	in		Specific gravity. Water=1	Air=1
Wood	1741	Platinum	21·50	
Descotils: Tennant	1803	Iridium	21·15	
		Gold	19·26	
Klaproth	1789	Uranium	18·40	
d'Elhujar	1783	Tungsten	18·30	
		Mercury	15·60	
		liquid	13·60	
Crookes: Lamy	1862	Thallium	11·90	
Wollaston	1803	Palladium	11·80	
		Lead	11·33	
Wollaston	1803	Rhodium	11·00	
		Silver	10·57	
S. Tennant	1803	Osmium		
		Bismuth	9·80	
		Copper	8·94	
Cronstedt	1751	Nickel	8·82	
Hjelm	1782	Molybdenum	8·63	
Brandt	1733	Cobalt	8·51	
Stromeyer	1818	Cadmium	8·45	
Gahn: Scheele	1774	Manganese	8·02	
		Iron	7·84	
		Tin	7·30	
		Zinc	7·13	
Vauquelin	1797	Chromium	7·01	
		Antimony	6·72	
Gregor	1791	Titanium		
Brandt	1733	Arsenic	5·63	10·40
Davy	1807	Barium	4·00	
Wöhler	1828	Aluminium	2·56	
Davy	1807	Strontium	2·54	
Wöhler	1828	Glucinum	2·10	
Bussy	1829	Magnesium	1·74	
Davy	1807	Calcium	1·58	
Bunsen	1860	Rubidium	1·52	
Davy	1807	Sodium	0·97	
,,	,,	Potassium	0·86	
Mosander	1839	Lanthanum	0·83	
Arfwedson	1818	Lithium	0·59	
		Hydrogen		0·0691
Rutherford		Nitrogen		0·9713
Priestley	1774	Oxygen		1·1056
Scheele	1774	Chlorine		2·47
		liquid	1·33	
Brandt	1769	Phosphorus	1·84	4·42
		red	1·96	
		Sulphur	1·98	6·62
		trimetric	2·07	
		Carbon	2·27	
		crystalline	3·53	
Gay-Lussac Thénard Davy	1808	Boron	2·63	
Berzelius	1810	Silicon	2·34	
		crystalline	2·49	
Balard	1826	Bromine	3	5·54
		liquid	3·19	
Berzelius	1817	Selenium	4·28	8·20
			4·80	
Courtois	1811	Iodine	4·95	8·72
Müller	1782	Tellurium	6·24	

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ls occur native, viz. gold, platinum, palladium, iridium, and rhodium,
lways found in the metallic state—silver, copper, mercury, bismuth,
rten found in the metallic state—iron, antimony, lead? zinc? which
nd in that state.
art, metals occur naturally as constituents of various minerals, in
mbined with oxygen, sulphur, chlorine, or arsenic, &c., in various
des.
s only three occur native to any considerable extent, viz. nitrogen,
ur. Carbon and selenium occur but rarely in an isolated state.
ether fluorine has yet been obtained in the free state, even arti-
).
characters and relations of metals and of metalloïds, there are
t as in their physical characters. These differences, however, are
the functions which the substances of one or other class perform,
with other substances, than by the capability of direct combination
hich is considerably influenced by various physical conditions, such
ate of aggregation, &c.; hence also this mode of chemical action
regarded merely as a phase of some more general dynamic pro-
s the exercise of a peculiar force, inherent in the different elementary
CHEMICAL AFFINITY, i. 850 *et seq.*) But in any case, the existence
nds, and their characters in relation to other substances, must be
of the same mutual activity which determines chemical combina-
elementary substances are more or less capable of existing in a state
nation with each other; but those possessing this capability in the
, as a rule, either the most opposite in their general chemical rela-
le of assuming special functions in relation to certain others. The
ces possessing the most universal capability of existing in combina-
nd of direct combination, are fluorine? oxygen, sulphur, chlorine,
d some of the metals.
xygen, which present the most decided differences in their general
may be taken as typical of the two classes of elementary substances
talloïds—the one representing the basylous, and the other the
ts of compounds. (Graham.)
hlorous characters of the elementary substances are not however abso-
s in the case of fluorine and oxygen. On the contrary, they vary ac-
of substances existing in combination. Thus, for instance, chlorine
th basylous in relation to oxygen, but chlorous in relation to hydro-
elementary substances; again, among the metals which are generally
elations to other substances, some are capable of existing in combi-
in relation to which they are then feebly chlorous.
ubstances consisting of two elementary radicles, their chemical
tions to each other generally approximate to the basylous or chlorous
ess in proportion to the relative preponderance of one or other of
one of the constituents. Thus, for example, in water the relatively
rous characters of hydrogen and oxygen are so nearly balanced
stitute of any chemical activity as an independent substance, and
s exhibit is, according to circumstances, sometimes basylous, as in
rate, &c., and sometimes chlorous, as in potassium-hydrate, calcium-

acid, however, the chlorous character of chlorine relatively to
that of oxygen, in such a degree that this substance is decidedly
to those substances with which it can exist in combination. But
id, though chlorine is basylous relatively to oxygen, that substance
n its compounds. In soda and sodium-chloride, on the contrary,
cter of sodium exceeds that of hydrogen, relatively to oxygen and
degree that the former is highly basylous, and the latter slightly so.
tivity of compounds as independent substances, is not by any means
hat of their constituents; thus, for instance, nitrogen is one of the
ubstances, but its compound with hydrogen is a powerful alkali,
npounds with oxygen are powerful acids.
in which two elementary substances are combined also influences
cters and relations of the compound. Thus, in sodium-peroxide,
s much oxygen as soda does in proportion to sodium, the basylous
rs, and this compound is destitute of any chemical activity as an in-
ee. Again, manganous oxide is highly basylous, and manganic oxide
he peroxide is indifferent, and the higher oxides are chlorous. In
ompounds of nitrogen and of chlorine, bromine, iodine, &c. with
cidedly chlorous in proportion to the amount of oxygen they contain

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The chemical function of manganese in manganous ox
that which it exercises in manganic or permanganic a
metal corresponds with, and is chemically equivalent
latter case it corresponds with, and is equivalent to, ch
and nitrous acids, and to chlorine in perchloric acid.
and EQUIVALENTS, ii. 491.)

Certain compounds of elementary substances prese
relations and functions, a very close analogy with the
instance, cyanogen (see ii. 275) and the hydrocarbon ra

Compounds are usually named generically accordin
and specifically according to their basylous constituer
oxygen, sulphur, or chlorine, &c., are the chlorous
sulphides, chlorides, &c. (see NOMENCLATURE). In th
the relative basylous and chlorous functions of the con
easily determinable, names of a more arbitrary nature
instance, the compounds of metals with each other are
in which one of the constituents is mercury are termec

Since the specific descriptions of particular compou
respective heads, it does not come within the scope of
than point out the leading characteristic features of
compounds, viz. oxides, sulphides, &c.

Oxides. All the elementary substances, except fluo
combination with oxygen, in one or several proportions

The physical characters of oxides are generally ve
constituent basylous radicles. Among the metalloïdal
ordinary conditions, as carbonic oxide, carbonic acid,*
sulphurous acid, &c.; some are liquid, as nitrous acid;
sulphuric acid, silica, &c. Among the metallic oxides,
volatilisable, as arsenious acid, antimonious oxide; th
infusible and insoluble in water. Formerly metallic
their production was termed calcination. (See GAS

Many oxides occur native in great abundance; thus
carbonic acid is a constituent of the atmosphere and of
stances. Silica also is very abundant both in the state
as a constituent of numerous minerals and rocks. Sul
a constituent of various minerals, as gypsum, selenite
occurs in the lagoons of Italy, and in some minerals:
distributed throughout the mineral kingdom, in small
abundantly in plants and animals. Among the metalli
the alkalis are probably the most abundant; exist
minerals and rocks. Among the compounds of the
oxides of iron, manganese, and zinc are the most a
combination with carbonic acid, silica, &c.

The chemical relations of the oxides are as dive
stances. Among the metalloïdal oxides containing the
some are characterised by their chemical indifferenc
relation to most other substances, as for instance car
Those containing larger proportions of oxygen are pos
activity; and, in their compounds with other oxides,
generally of a more or less decidedly chlorous character,
and carbonic acids.

The metallic oxides containing the smallest propor
characterised by their chemical indifference, as for i
they more generally present relations of a basylous n
other oxides, as for instance potash, soda, zinc-oxide, s
containing larger proportions of oxygen, some, such
present this character in a less marked degree, and
they are chlorous, as in potash-aluminate, &c. Ot
still larger proportions of oxygen, such as mangan
indifferent as individual substances; but the oxides co
of oxygen are in many cases decidedly chlorous in thei
as for instance, manganic acid, permanganic acid, stan

The chemical relations of compounds consisting of tw
of a nature corresponding to those of hydrochloric a
other chlorides, and the mutual relations of their const

* The word "acid" in this article is used in the sense of *anhyd*
acid CO^2; nitric acid N^2O^5, &c.

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rine in hydrochloric acid. (See SALTS; and ACIDS, i. 39; ALKALI, 9.)

taining the largest proportions of oxygen are decomposed at various he action of heat alone, yielding oxygen-gas and lower oxides. id, which is readily decomposed by heat, most of the other higher loïds which are known in a separate state, are capable of supporting nperature without decomposition. The sesquioxides and peroxides rally decomposed by heat into oxygen and lower oxides, and all the ld, platinum, &c., are decomposed by moderate degrees of heat into e respective metals. Some oxides, on the contrary, combine with a oxygen, either at the ordinary temperature, as for instance man- oxides, or when heated in contact with oxygen or atmospheric air, e. This change takes place most readily in some cases when the ation with water, or when water is present.

be decomposed to a greater or less extent by the simultaneous action e other substance capable of combining with oxygen, and of abstract- de operated upon, so as to form an oxide of greater stability under This **reduction**, as it is termed, is complete when the whole of rated from the basylous radicle, and partial when there is only a ced. The most powerful reducing agents are the alkali-metals, oxide, and carbon. Even carbonic oxide is decomposed by potas- with the aid of heat. The oxides of the metalloïds are mostly ction by carbon with the aid of heat. Among metallic oxides those d, bismuth, &c., are completely reduced by hydrogen at a red heat; anese and uranium, &c., are but partially reduced; oxide of zinc with e lower oxides of chromium, manganese and uranium, and the oxides alkali-metals are not affected by hydrogen. In the reduction of y means of carbonic oxide or carbon, the metal eliminated often a state of combination with it. At very high temperatures, carbon les which are not affected by hydrogen, as for instance soda and eat.

tion of a metallic oxide by carbon is effected at a comparatively low nic acid is formed; but when it takes place only at a very high nic oxide is produced.

f metallic oxides may also be effected by heating them with metals ess readily reduced. Thus potassium reduces several metallic oxides, ferric oxide at a red heat; but at a white heat, potash is decomposed ult in this latter case may be due to the volatility of potassium at and the consequent removal of small portions reduced under the ponderating mass of iron, so that this action takes place repeatedly f the potash is decomposed, and without any possibility of action ium and oxide of iron.

heat and reducing agents upon compound oxides, such as sulphates, here may be produced a compound of the metal with the chlorous n-sulphide, by heating to redness a mixture of the corresponding on. If the radicle of the chlorous constituent of the compound does the metal under the circumstances, it may be volatilised in the ide, as in the reduction of nitrates.

l oxides, such as carbonates, nitrates, &c., are decomposed by the at, the acid being eliminated either unaltered or decomposed, and e remaining either in the same state as it existed in the original a higher state of oxidation; thus ferrous carbonate yields by rric oxide and a mixture of carbonic oxide with carbonic acid.

and metalloïds do not, under any known circumstances, combine en; for example, gold, platinum, nitrogen, chlorine, bromine, iodine, rs are capable of combining directly with oxygen, some of them at ures, as for instance sodium, potassium, &c.; others like copper, iron, hosphorus, &c., when heated to temperatures differing for each. In t combination with oxygen is attended with evolution of heat, and pidly, it is also attended with evolution of light. (See COMBUSTION,

ondition of substances capable of combining directly with oxygen, ich the facility with which the combination takes place. A state of n is most favourable, while a compact condition is most opposed to cially when the resulting oxide is infusible at the temperature combination, and forms a protecting crust over the surface of the pulverulent copper, heated to about 450° C., takes fire in oxygen gas,

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and is completely converted into oxide; but a plate of
merely becomes covered with a crust of oxide. On
continues to burn in oxygen gas, because the resulting
ture produced, and thus a fresh metallic surface is
gas.

The indirect oxidation of metals and metalloïds
with substances which evolve oxygen when heated,
Some metals, such as iron, zinc, &c., decompose wat
form oxides which combine with the acid. Others deco
temperature, like sodium, or by the aid of heat, like
Others again decompose water in the presence of an all
aluminium and zinc. The behaviour of iron with wate
with hydrogen, present a striking illustration of the i
exercise of chemical affinity. The production of ferr
reduction of the same substance in the other, a
respective preponderance of water-vapour relatively
relatively to water-vapour, and also to the constant
the water-vapour which are produced in the two ca
A similar influence is also manifested in the reduct
(Deville.)

The facility with which different metals combine
ordinary circumstances, varies very much. While
oxidised even in dry air, neither gold, silver, nor platin
Some metals, such as iron, however, which remain pe
oxygen, rapidly become oxidised in moist air, and cov
presence of acid vapours in the atmosphere facilitate
metals, but in the case of some it does not extend bey
stance, zinc, when superficially oxidised by exposure to
further oxidation, the portions underlying the crust of o
In the case of iron, on the contrary, the oxidation progr
is converted into oxide, or as it is termed rust, and it
rapidity after the first oxidation of the surface has tak
relation of the iron to oxygen is augmented by its cont
combination with oxygen is thereby facilitated so mu
decomposing water.

A different application of the same principle may be
the oxidation of iron. Thus if the metal is placed in
renders iron electronegative in relation to it, the affini
and it becomes less liable to oxidation than it would
has been practically applied in the galvanising of iron
with a thin layer of zinc which becomes electropositive
the zinc is thus rendered more liable to oxidation, it
oxidation of the zinc is only superficial, and the produc
it prevents further action.

Sulphides. These form a very numerous class o
with the chemical analogy between sulphur and oxyge
tions considerable similarity to the oxides. They
sulphur, and are accordingly termed *proto-*, *sesqui-*, *di-*,
the exception of carbon-disulphide, which correspo
phides of the metalloïds are but little known: there a
phosphorus, and probably more than one sulphide o
Journ. Sci. iv.; Soubeiran, Ann. Ch. Phys. [2] lxvi

The sulphides are capable of forming compounds wit
analogous to the compounds of oxides, in which the su
mentary radicles, and those containing the smallest prop
bases—are basylous in relation to sulphides containi
and less basylous radicles—sulpho-acids. Thus po
carbon-disulphide and with arsenic-pentasulphide, form
and potassium-sulph-arsenate. The sulphides of th
called liver of sulphur.

Many sulphides combine with water and some other
and iodides, &c.

The physical characters of some metallic sulphides
metals in certain particulars, such as the peculiar opaci
when they are in a crystalline condition. They are
and of a grey, pale yellow, or dark brown colour. The
are soluble in water, most of the others are insoluble.

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g oxides, and some are volatilisable, as mercury-sulphide, arsenic-
sulphide is an oily liquid, insoluble in water.
occur native in great abundance in the various forms of pyrites,
. They are the principal sources from which certain metals, such
re extracted.
hen heated out of contact with atmospheric air, do not undergo
his is the case chiefly with those containing the smallest propor-
as the protosulphides of iron and zinc. Sulphides containing
sulphur are partially decomposed by heat, losing part of their
verted into lower sulphides, or partially reduced, as in the case of
sulphides of gold and platinum are completely reduced by heat.
be decomposed by the simultaneous action of heat and of substances
with sulphur. Thus, for instance, silver, copper, bismuth, tin, and
e reduced by hydrogen; copper, lead, mercury, and antimony sul-
heating with iron; but, in this case, some of the sulphide escapes
mbines with the iron-sulphide produced, forming a sulpho-salt.
e not reduced by heat alone, are always decomposed when heated
n or atmospheric air. Those of the alkali- and earth-metals are
ates by this means. Zinc, iron, manganese, copper, lead, and
e converted into oxides, and sulphurous acid is produced; but
is not above dull redness, some sulphate is formed by direct
and silver sulphides are completely reduced to the metallic state.
s gradually undergo alteration by mere exposure to the atmo-
generally limited to the production of sulphates, unless the oxida-
idly that the heat generated is sufficient to decompose the sulphate
e production of some metals for use in the arts, the separation of
ve minerals is effected chiefly by means of this action in the
(See METALLURGY.)
ides are also decomposed by heating them in contact with water-
on of metallic oxides and sulphuretted hydrogen: lead, antimony,
s are but partially or little affected, and the sulphides of alkali-
nverted into sulphates, hydrogen being eliminated.
re decomposed in like manner when heated with metallic oxides
s, yielding sulphurous acid and the metal of both the sulphide
sulphates and nitrates exercise a similar action, yielding various
c oxide and basic sulphates according to the proportions of the

ides are decomposed by acids in the presence of water, sulphur-
evolved, while the metal enters into combination with the acid
of the acid. Nitric acid when concentrated decomposes most
ion of metallic oxide, sulphuric acid, sulphur, and a lower oxide of
tic acid acts still more energetically in a similar manner.
and metalloïds are capable of combining directly with sulphur
nder suitable conditions. Gold and zinc do not combine directly
mbination of metals with sulphur is attended with great evolu-
of light when it takes place rapidly, being in fact a true case of
ulphur takes the part of oxygen.
roduced by the action of metals upon sulphydric acid, both slowly
erature, and more rapidly by the aid of heat. Metallic oxides
sulphur yield sulphurous acid and sulphides; sometimes a com-
oxide, as in the case of manganese. The alkalis and earths do
acid in this way, but hyposulphurous or sulphuric acid, which
on with a portion of the base—liver of sulphur. Metallic
carbon are reduced, carbonic acid or carbonic oxide and sulphides
rogen gas exercises the same reducing action with production of
es heated in contact with sulphuretted hydrogen or vapour of
converted into sulphides, with simultaneous production of water
arbonic oxide according to circumstances.
compounds yield precipitates of metallic sulphides when mixed
ydric acid, or of soluble sulphides. In the case of metals
ecomposed by dilute acids, the sulphides are not precipitated
li added to neutralise the acid of the metallic salt.
are also produced by the reduction of sulphates by organic
tive sulphides have no doubt been formed in this way.
ese compounds are but little known in a definite state; but they
l analogous to the sulphides in their chemical characters. The
e mostly brittle and fusible, and the presence of phosphorus in

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metals renders them hard and brittle. (See Copp
Lead, iii. 557.)

The phosphides of the alkali- and earth-metals
water, yielding oxides and phosphoretted hydrog
converted by ignition in contact with air into basic
being volatilised.

Metallic phosphides may be produced, either by
by the reduction of phosphates with carbon or hyd
phoretted hydrogen upon solutions of metallic co
combined with phosphorus by any of these method

Chlorides.—All the elementary radicles, excepti
of existing in combination with chlorine. The con
generally correspond to the oxides. (See Metalli

Among the chlorides of the metalloïds, some cor
the respective oxides, sulphides, &c. (See i. 899, 7

Bromides.—(See i. 672 *et seq.*)

Iodides.—(See iii. 284.)

Fluorides.—(See ii. 670 *et seq.*)

Nitrides.—With the exception of the nitride
these compounds are but little known. The titan
remarkable. Several other metals and metalloïds
with nitrogen in several proportions. (See Carba
i. 635; Copper, ii. 67; Iron, iii. 391; Magnesium,

Carbides.—Several metals appear to be capable
but their chemical history is little known. The m
(iii. 371 and 329; also Copper, ii. 52). Manganes
carbon analogous to the iron carbides.

Silicides.—The compounds of silicium with th
the carbides. (See Iron, iii. 334, and Manganese,

Alloys.—Most metals are probably, to some ex
of combination with each other in definite propor
these compounds in a separate condition, since they
melted metals, and do not generally differ so wide
points, from the metals they may be mixed with, a
in a definite condition. Exceptions to this are met
lead (iii. 504 *et seq.*), the crystallisation of brass
metal (ii. 44).

Some metals cannot be made to mix or combi
together, except in very unequal proportions. Thus
and zinc only 1·2 per cent. lead (see Matthiessen
Even when metals are miscible in all proportions, it
actual chemical combination, as in the case of potass

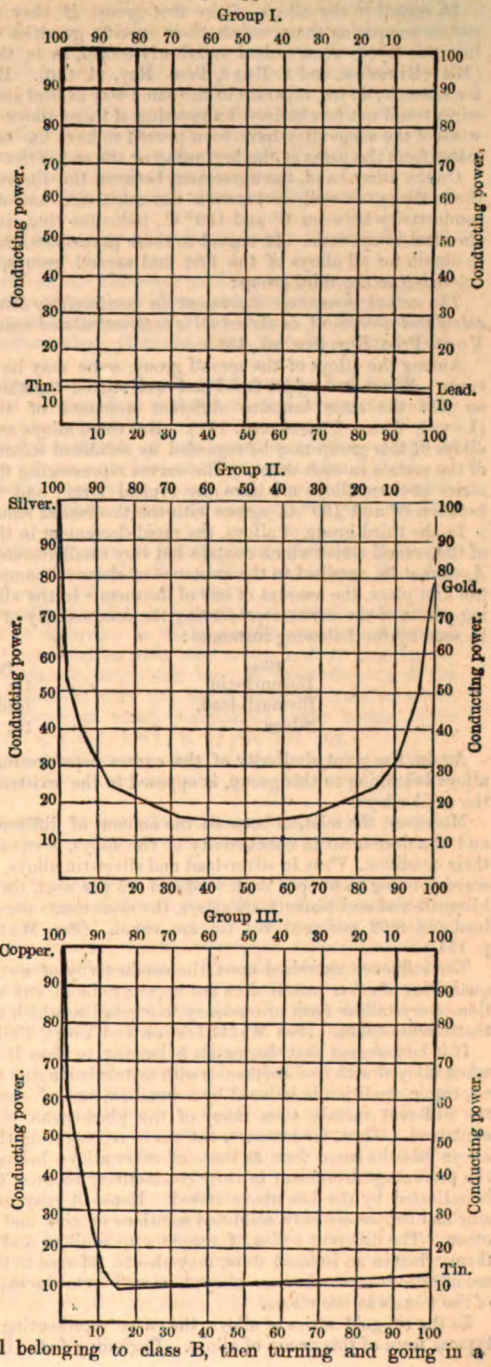
The chemical force capable of being exerted betw
be expected to be very feeble, and the consequent st
be very easily disturbed by the influence of othe
metallic compounds is however greater in prop
dissimilarity of the metals they contain. But in
metals, the alteration of physical characters, which
cal combination, does not take place to any great
compounds of metals are still metallic in their gen
is no such transmutation of the individuality of th
the combination of a metal with oxygen, or sulphur,
characters in alloys is generally limited to the colou
and it is only when the constituent metals are capa
relations, that these compounds are distinguished by

The formation of actual chemical compounds is i
metals are melted together, by several phenomena
the case of platinum and tin, copper and zinc, &c.
from that of mere mixtures of the metals. In the soli
does not always fall uniformly, but often remains stat
may be regarded as the solidifying points of the co
and lead melted together in any proportions always
at 187° C. The melting point of an alloy is often ver
fication, and it is generally lower than the mean melt

But though metals may combine when melted to

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ter the solidification of the mass, and the wide differences between solidifying points of certain alloys appear to indicate that the ompounds n range of hiessen ts, 1863, probable f an alloy he liquid that of— metal in ical com- nical mix- lution or all of the milar dif- as to its lid state. the con- and elec- the cha- lated to al nature ct to elec- divides ses, viz.: h, when ther, con- he ratios olumes— dmium. h, when other, or ass A, do ricity in relative ys in a that cal- mean of ismuth, um, pal- inium, ver, &c. resenting different e the re- e accom- belonging netals in straight lead-tin e type. curves of n class B ement on urve, the ing con- y nearly at of the given as curves of class A B show on the



h the metal belonging to class B, then turning and going in a

straight line to the other side, beginning with the m
of the tin-copper alloys is given as the type.

In regard to the alloys of the first group, if they
metals composing them, unless their specific gravities
into two layers when melted and slowly cooled, as in
(Matthiessen and v. Bose, Proc. Roy. xi. 430).
for example, do not separate in the same way as lead a
wires could not be obtained by pressing if these alloy
wires of the same alloy have been proved to have the
taken from the press at the beginning or the end of th

On the other hand, the agreement between the theo
these alloys, as well as between the calculated and
conductivity between 0° and 100° C., indicates that,
chemical compounds. In regard to these particulars,
to obtain for all alloys of the first and second group
belonging to the third group:

The actual percentage decrement in conductivity b
calculated decrement, as the actual is to the calculated co
Vogt, Proc. Roy. Soc. xii. 652.)

Among the alloys of the second group, some may b
tures. Silver and copper fused and well stirred toget
so that the mass contains different amounts of
(Levol, Journ. Pharm. xvii. 111). But these alloys
alloys of this group may be regarded as solidified solu
of the metals in each other. The curves representing
series of these alloys all have the typical form; and
between 0° and 100° C. agrees with the theoretical a

In the third group of alloys, the rapid decrement in
of the several series which contain but very small amou
A, cannot be ascribed to the existence of chemical com
the first place, the amount of one of the metals in the
ing-points of the curves representing the conductivity
be seen by the following instances:

Alloy.	
Bismuth-tin.	ti
Bismuth-lead.	le
Silver.	ti

Again, the great similarity of the curves represent
alloys belonging to this group, is opposed to the exist
the solid alloys.

Moreover, the relation between the amount of diffe
and the decrement in conductivity of the alloys, is eq
their condition. Thus in silver-lead and silver-tin alloy
corresponding to 0·9 per cent. lead and 0·7 per cent. t
bismuth-lead and bismuth-tin alloys, the decrements c
lead and 0·62 per cent. vol. tin are equal. (See M
p. 171.)

The influence exercised upon the conductivity of m
quantities of other metals does not appear to be in an
tion of crystalline form or tendency to crystallise whic
that circumstance. (See Matthiessen and Vogt, P

If it be assumed that the metals belonging to class
when alloyed with one another or with metals belongin
allotropic condition is induced by a small amount of ot
the different metals, then many of the phenomena
explained. Thus, for instance, the curve representing
alloys has the same form as those of other alloys bel
the percentage decrement in their conductivity betwee
is indicated by the law above stated. Hence it may
zinc and copper are only solidified solutions of zinc a
other. The different action of reagents upon alloys a
them, when in an isolated state, may also be referred t
modifications when they are alloyed, as well as to the
of the metals in the alloys.

In the tin-gold series of alloys, the curve representi
typical form of this group of alloys. Beginning from

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Au^2,* then a gradual increment to the alloy SnAu, and then a de-
d from the alloy containing 2·7 per cent. tin to pure gold, the
y is represented by a straight line. These irregularities may be
that the alloys corresponding to the turning-points of the curve
nds, for they have definite composition; they contain large
: Sn^5Au^2 = 60 per cent.; SnAu = 37 per cent.; and $SnAu^4$ = 13
the specific gravity of the alloy Sn^5Au is almost equal to that
expands and $SnAu^2$ contracts more than any of the other tin-
r, the percentage decrement in the conductivity of these alloys
. does not conform to the law above stated (p. 943). Tin and
ch other very readily, with evolution of heat.
ssifies the solid alloys composed of two metals according to their

s of one metal in another—lead-tin, cadmium-tin, zinc-tin, lead-
mium alloys.
s of one metal in the allotropic modification of another—lead-
in-copper, zinc-copper, lead-silver, and tin-silver alloys.
ns of allotropic modifications of the metals in each other—
silver, palladium-silver, platinum-silver, gold-copper, and gold-

nds of the alloys corresponding to Sn^5Au, Sn^2Au and Au^2Sn.
s of chemical compounds in each other—the alloys intermediate
nding to the above formulæ.
ures of solidified solutions of one metal in another—alloys of
g more than 1·2 per cent. lead or 1·6 per cent. zinc.
res of solidified solutions of one metal in the allotropic modifi-
ys of zinc and bismuth containing more than 14 per cent. zinc
nt. bismuth.
res of solidified solutions of allotropic modifications of the two
-most of the silver-copper alloys. (Matthiessen, Brit. Ass. *Chemical Nature of Alloys*, pp. 37–48.)
he rule generally obtaining in respect to chemical combination,
nt the greatest difference in their general chemical characters
existing in combination with each other, and of forming de-
s arsenic, antimony, &c., which are the most chlorous of the
definite compounds with the more basylous metals—silver,
obalt, &c., many of which compounds occur native. (See
ONIDES, i. 316, 370, 591, 1041; ii. 41; iii. 368, 532.)
arsenic when heated out of contact with air; but by heating in
are converted into oxides or basic arsenates, while arsenious

re often formed in metallurgical operations with arsenical
balt, nickel, or iron, and collect in a separate layer between the
sulphides.
ers of alloys, though they always retain the prominent cha-
some respects very different from those of the metals they
der these latter useful in the arts. Thus the alloy consisting
weight of zinc, is much harder than pure copper, and at the
uctile (see BRASS, ii. 47 *et seq.*). The alloy of copper with one-
is much harder than copper, is well calculated for casting, and
for the construction of ordnance (see BRONZE, ii. 43 *et seq.*).
th one-ninth its weight of aluminium is hard, tenacious, and
UM BRONZE, i. 155). The alloy of copper with one-fourth its
rd, and being highly sonorous is well suited for bells, &c. The
f its weight of tin is white, and capable of receiving such a high
for the reflectors of telescopes. (See SPECULUM METAL, ii. 43.)
h one-fourth its weight of antimony is readily fusible, much
ot brittle like antimony-bismuth or zinc, and is well suited by
pe-founding (see TYPE-METAL, i. 316; iii. p. 532). Other alloys
under the heads of the several metals they contain.
f reagents upon alloys is sometimes very different from their ac-
eparate state; thus platinum, when alloyed with silver, is readily
, but is not affected by that acid when unalloyed. On the con-
separate state is readily dissolved by nitric acid, is not dis-
ed with gold in proportions much less than one-fourth of the

* S = 118; Au = 196.

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Analysis of Alloys.—The number of metals whic
various alloys used in the arts is not very conside
the following systematic mode of testing alloys will
metals they contain.

The finely divided substance is covered with str
the reaction is assisted by the application of a gent

I. *No reaction takes place*, and

A. The substance remains unaltered, indicating
but **gold** and **platinum.**

II. *A reaction takes place, red nitrous fumes bein*

B. Solution of the substance takes place withc
ing the absence of **gold** (**platinum?**), **antimony**

1. The solution may contain all the other metals
copper, lead, silver, bismuth, mercury, arse
aluminium.

C. The solution is partial, and the residue is—

2. *Metallic*, or a *black powder*, indicating the
perhaps **antimony** and **tin** in small proportions.

3. *White*, indicating the presence of **antimon**
platinum in small proportions.

D. No solution takes place, indicating the absen
num, antimony, tin, and perhaps **silver** and
residue may be—

4. *White*, indicating the same as 3.

The solution, 1, is in all cases to be treated in th
remains undissolved, it is to be separated by de
filtration after the excess of acid has been remo
metals are then to be tested for in the clear solutio

When, on treatment with nitric acid, there is pr
to be collected upon a filter, washed, and tested for

When the substance is not acted upon by nitr
dissolved, the residue, 2, or the unaltered substanc
three parts hydrochloric acid and one part nitric ac
The result of this treatment may be either—

5. *Partial solution* and the separation of a white i
or (less probable) chloride of **lead.**

6. *Complete solution.* Both in this and the prev
this group A will be dissolved, and the solution m
which should be tested for in the usual manner.
ii. 928.)

The chloride solution, 5 and 6, may also contai
dissolved by nitric acid when alloyed with gold or

METALLURGY. *Hüttenkunde. Métallurgie*
the various minerals found in the earth, and of conv
the purposes of the arts, which constitutes metallu
a number of operations which are of a purely mec
come within the province of this work. But many
metallurgy involve processes which are essentially c
tion of the general principles upon which these ope
be directed in this article. Information on the mec
be found in *Ure's Dictionary of Arts, Manufactures*
MINING, and ORES, DRESSING OF.

The metals which are largely used in the arts, viz
antimony, bismuth, nickel, mercury, silver
exception of the last two, chiefly found in the state
substances, constituting a variety of minerals, amon
ciently considerable amount of the several metals to
tracted, are called ores, when they occur in sufficient

The production of the alkali- and earth-met
extensively than it was, is a branch of industry ap
manufactory than to metallurgy; this is also the cas
the compounds of cobalt, chromium, and arse
the ores of these metals.

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nds which are most frequent as ores are:—
mple, such as stannic oxide in tin-stone, ferric oxide in hæmatite,
uch as ferroso-ferric oxide in magnetic iron ore, and some saline
tes, and, in small quantity, silicates, sulphates, &c.
er simple, such as galena, blende, grey antimony; or compound
per pyrites, zinkenite, miargyrite.
rally in small quantity, and mixed with other ores.

rely occur in a separate state, but are more or less mixed with
ch they are imbedded. Gang (*Gangue; gangart*), constituting
ted in more or less horizontal or vertical positions relatively to
ociated with, and are accordingly distinguished by the terms
lode (*Gang; filon*).
nerally met with in ores are either minerals containing other
ne ore they are associated with, or they are minerals which do
metals commonly used for technical purposes, as for instance
he numerous mineral silicates, felspar, hornblende, mica, &c.;
pitter spar, limestone, &c.; sulphates, heavy spar; fluorides, &c.,
ks adjoining the lode or bed. Sometimes these latter admixtures
tions by which the metals are extracted; sometimes they require
nically by various preliminary operations. (See Ores, Dressing
f Arts, Manufactures, and Mines, iii. 312.)
metal contain admixtures in small proportion of other metal-
perations by which the metal is extracted are in some cases con-
h the view of effecting a separation of the foreign metals; either
ue, as in the case of argentiferous lead and copper ores, or because
luence upon the qualities of the metal to be obtained from the
32; Lead, iii. 504 *et seq.*)
cters of the metals which it is the object of metallurgical opera-
it necessary that in most cases they should be melted before
al purposes, and the chemical nature of their ores is such as to
of powerful chemical agencies to effect the separation of the
ances they are combined with. For these reasons, the action of
he chemical activity of substances has been had recourse to in
ic operations by which chemical changes are to be effected in
terials operated upon, and the extraction of metals from their
commonly termed smelting. But there are other methods by
ay be extracted, and by which certain of them are to some extent
res without the aid of heat. According to these methods, the
d upon in such a manner as to convert the metal they contain
uble in water, and from the solution the metal is separated
of another metal upon the solution, or by galvanic action
y, *Ure's Dictionary of Arts, Manufactures, and Mines*, ii. 88).
icity, however, is chiefly applied in the working of certain metals
es, as in electroplating, and has not yet been rendered
tion of the ordinary metals from their ores. Among the other
metals from their ores in the wet way, the precipitation of
e extraction of silver from its ores by means of sodium-chloride,
ores has been converted into chloride (see Silver), as well as the
and gold ores by nitro-hydrochloric acid, are the only methods
carried on to any extent.

ations, conducted, as is usually the case, in the dry way, or with-
ter, and with the aid of a high temperature, there are two modes
erations are brought about in the ore or other materials operated
nd roasting. In the one case the material is mixed with some
mposes it, when one or other of them is rendered liquid by
nple, galena and metallic iron melted together yield metallic lead
When galena is melted with litharge or lead-sulphate in suitable
produced metallic lead and sulphurous acid (see *ante*, p. 482).
kes place when cupric sulphide and cupric oxide are melted
er, ii. 23 *et seq.*)
ion, viz. roasting, the ore, or other material, is subjected to the
nd of a gaseous substance capable of producing a chemical altera-
cilitate a subsequent operation. Thus, for instance, in copper
sisting of sulphides, are roasted in contact with atmospheric air
m to a great extent into oxides, and in the subsequent melting
s oxide is again converted into sulphide by reaction with the

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iron-sulphide remaining unoxidised, and is th
produced in the roasting. In the smelting of le
contact with atmospheric air, and is thus partial
which, in the subsequent melting operation, react
indicated.

In some cases the operation of melting is
oxidation, as in the separation of antimony from
in cupellation (see *ante*, p. 508 *et seq.*). Roastir
the object of effecting reduction, as in the conversi
into sulphides and arsenides by means of carbu
the chief ultimate effect produced by roasting
change; while the ultimate effect produced by r
These operations are in some way involved in th
ores; a description of the general conditions und
general features of the chemical processes which
therefore exhibit the chief chemical principles of
tion will be found under the heads of the respecti

Roasting of Ores and Meta

Ores and intermediate products are roasted eit
as large lumps, according to their nature. The
case sufficient to cause fusion, or aggregation of
sary to keep the material operated upon stirred a
the action of the gas by which chemical alteratio
Roasting is conducted, sometimes in kilns, son
cially constructed for the purpose, and sometime
heaps with alternate layers of fuel, which are ign
consumed.

Oxidising roasting is always effected by mea
air made to pass over the material at a suitable te
duced by roasting is either a mere combination
iron ore, which is thus converted into ferric oxi
separation, more or less complete, of some const
as in roasting sulphides, when a portion of the
acid and volatilised, while the metal is converte
the sulphur is oxidised into sulphuric acid, which
oxide.

The different metallic sulphides present very di
tions: thus—

Iron-protosulphide is partially converted into
degree of heat is decomposed into sulphurous acid
sulphate, and ferrous oxide. At a still higher te
also decomposed, yielding at last ferric oxide. I
ever, it is very difficult to effect the entire sepa
by roasting, even when the material is finely divi
the surface frequently changed by stirring meanw
Zinc-sulphide undergoes oxidation very slowly
oxide, which at a higher temperature loses sulphu
verted into pure oxide. This result, however, is
case of iron-sulphide; but the roasting of zinc-sul
as it is less liable to undergo partial fusion than
Copper-sulphide, when carefully roasted, is c
oxide and cupric sulphate. So long as sulphur
oxidation of sulphur, cupric oxide cannot be form
tact with sulphurous acid is partially reduced, cup
produced; but so soon as all the copper-sulphide
ture, the cuprous oxide begins to be further oxi
cupric sulphate undergoes decomposition, sulphur
In the imperfect roasting of copper-sulphide, w
containing that substance are operated upon on th
of cuprous oxide, cupric sulphate, copper-sulphid
appears to be produced in those places where the
while surrounded by an atmosphere of sulphuro
reduce cupric oxide to cuprous oxide under the sa
Lead-sulphide is difficult to roast, since it is

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of lead-sulphate and lead-oxide, from which the sulphuric acid even when it is heated so high as to melt.
is so fusible that it is very difficult to roast completely.
hide is also very difficult to roast for the same reason. There is a mixture of trioxide, pentoxide, and sulphide of antimony. If the ion of the pentoxide is volatilised.
and trisulphide are decomposed by roasting, yielding arsenious and oth of which are volatilised.
is converted by roasting into metallic mercury and sulphurous acid.
dergoes the same alteration by roasting.
entirely converted into metallic silver. But when it is roasted sulphides, such as iron- or copper-sulphide, some silver-sulphate is hich by increase of temperature is decomposed into metallic silver, d oxygen.
an be easily converted by roasting into a mixture of nickel-oxide only a small admixture of unaltered sulphide. So long as sul-erated abundantly, nickel-oxide only is produced, and this after-xidised.
ehaves in a similar manner to nickel-sulphide, except that some ways produced.
sulphides, modifications of the chemical changes are often effected s, such as carbonic oxide or hydrocarbons, are mixed with the at- perhaps, when water vapour is present, as is almost always the n as conducted on the large scale.
mical alterations which arsenides and phosphides undergo xidising roasting, are less known than those of sulphides; but, as ic is more difficult to separate than sulphur, and phosphorus can a very small extent, on account of the stability of phosphoric acid s.

oasting. The sulphides containing the largest proportions of sul-yrites, &c., lose part of their sulphur by direct decomposition, in mere action of heat. Hydrated compounds, carbonates, &c., are the same manner. But more generally the volatilisation of some aterial roasted, is the result of previous chemical alteration, and volatile compound by the chemical action of the atmosphere in is conducted.

roasting is effected by means of an atmosphere containing ric acid, or chlorides. Silver ores are often subjected to this treat-e silver into chloride. At the same time, iron is partially volatilised rsenic, antimony, zinc, tin, bismuth, mercury, chromium and sulphur as chlorides.

ting. When iron ores are heated in an atmosphere of reducing nic oxide or hydrocarbons, metallic iron is produced; and in iron e always precedes the actual melting. When such ores contain zinc h metals are reduced, and the zinc is volatilised at a sufficiently Under similar conditions arsenates and arsenites yield a portion of metallic state. This is also the case with antimonates, tellurates, tes.

TALLURGICAL PRODUCTS FOR THE EXTRACTION AND SEPARATION OF METALS.

subjected to the operation of melting without having previously er treatment, such as roasting, &c. This preliminary treatment is the earliest stage of the melting operation, as in the smelting of the upper parts of the blast-furnace, are subjected to the action of gases before sinking down to that part of the furnace where fusion RON, *ante*, pp. 357, 364.) But in such cases, the chemical nature of ed in the roasting and the melting is exactly the same as when e conducted separately.
erations which take place in the operation of melting sometimes ration of a metal in the state of regulus, sometimes only ration of the substances combined with it, and the production of a *te*), or compound containing a larger proportion of metal than the upon. (See COPPER, ii. 23 *et seq.*) These results are often due l action of the several constituents of the ore, which has undergone

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substance by means of which the de
stance to be added will of course b
operated upon, and by the kind of c
antimony ore, consisting of the trisu
reacting with which it yields metall
In all cases it is essential that in
chemical alteration of the materials
products. It is not often that this
more of the products. More freque
obtained separate only when they
mixing with each other while in th
that in melting operations the whc
that such a separation may readily
which it is the object of the metal
as regulus, from the other produc
metals are also sufficiently dense to
the other products of melting, thoug
With the object of facilitating th
action which takes place in meltin
mixed with some substance which
the products formed, and their sep
added with the object of rendering
being melted, or more readily fusib
(*Zuschlag ; fondant*).
In the first melting of ores co
obtained is not always the metal, ev
frequently a matt or mixture of su
the state of regulus, the matt for
taining much antimony, arsenic, &c
times formed, which separates betw
But ores very generally contain,
siliceous or earthy admixtures, orig
they are naturally associated. T
mechanical means, and since they s
quire to be converted into compound
gravity when melted, than the othe
this object are generally either—
Siliceous, such as quartz, sands
Earthy, such as lime, limestor
stances to be separated; by this
earthy silicates is formed, which is
such as fluor-spar, alkaline sal
The addition of fluxes in the melt
the fusion of the material operated
formed. Moreover, the resulting sl
products, collects above them, and
action of the furnace gases, which is
The melting operation is genera
the materials are mixed with the fu
are heated in a separate chamber b
bustion. Sometimes crucibles are u
contact with the fuel.

Reducing melting is generally
action of heat and the carbon, carbo
resulting from the combustion of the
equal degrees of chemical stability c
which they are reduced by those sub
bismuth, antimony, nickel, cobalt a
of red heat; while those of iron, m
or less intense degrees of white heat.
The mode in which reducing melt
easily fusible or infusible at any te
In the first case the material can be i
this cannot be effected, and the redu
resulting from the combustion of ca
p. 358.)

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metallic sulphides by melting is effected principally by means of
ad-sulphide melted with iron in equivalent proportions yields
iron-sulphide. With two equivalents of iron, there are produced
ron-sulphide containing metallic iron mechanically mixed. Zinc-
ely decomposed by iron, but a very high temperature is required.
partly decomposed by melting it with metallic iron, and there are
sisting of cuprous sulphide and iron-sulphide, and some metallic
des of copper and iron yield, on the contrary, a matt consisting of
n-sulphide and metallic iron. Lead-sulphide with two equivalents
att consisting of cuprous sulphide and metallic lead. Equal equi-
c lead and a matt consisting of cuprous sulphide and lead-sulphide.
take place between zinc-sulphide and copper.
ntirely decomposed by melting with an excess of tin, but in equal
y partly decomposed, and there are produced an alloy of tin and
sisting of tin-sulphide and lead-sulphide.
alkalis exercise a much more energetic action upon metallic sul-
with them, and though they cannot be employed in ordinary
ions, a similar action may be produced to some extent by means of
alis and carbon (**black flux**). Thus, when a metallic sulphide is
ient quantity of alkaline earth or alkali mixed with carbon, the
ce the sulphur combines with the alkali- or earth-metal, while the
combines with carbon. When an alkali is used, more or less of the
nerally remains undecomposed and dissolved in or combined with
.

ing is practised with the object of separating one metal from
ting sulphur from metallic sulphides by converting the sulphur, or
oved, into oxides, which may either be volatile as sulphurous acid,
ad, or capable of being rendered fusible by combination with cer-
d as fluxes.
is the oxidising agent most commonly employed; but sometimes
also used, which are capable of yielding oxygen at a high tempe-
en in the liquid state and in contact with the substances to be
ese are lead-oxide and oxy-salts, cupric sulphate, ferrous sulphate,
nitrates, &c.
amples will serve to illustrate the mode in which these oxidising
in the melting operation.
-Compounds of gold or silver with antimony, arsenic, or sulphur,
fficiently heated current of atmospheric air, are decomposed, and
ned in the pure state.
c air is passed over the surface of melted copper containing iron,
y, arsenic, and sulphur, the three latter are volatilised as oxides,
quid layer or scum collects upon the surface of the metal, consist-
cobalt- and lead-oxides, antimonic oxide, and cuprous oxide, until
almost pure. The greater the quantity of lead in proportion to the
more liquid is the layer which collects on the surface; and the
cker is this scum. In both cases the scum must be removed from
a fresh metallic surface may be exposed, and if it is not sufficiently
d by the current of air, the edges of the convex surface of melted
ipally collects must be raked off.
ld or silver with lead or bismuth are exposed in a melted state to
latter metals are oxidised, and pure gold or silver remains, together
l-oxide. A portion of the oxide is volatilised, and in the case of
lly, a small quantity of this metal is also volatilised. When small
etals, such as iron, cobalt, copper, &c., are present in such alloys,
nd the oxides are dissolved by the oxide of lead or bismuth.
d of arsenic, iron, cobalt, and nickel is melted in a current of air,
ide and cobalt-oxide produced may be dissolved by melted borax,
surface of the melted metal, arseniferous nickel may be obtained;
arsenic cannot be separated, because, in proportion as it is sepa-
oint of the remaining metal becomes higher, and it finally solidifies.
en litharge is melted with easily oxidisable metals, they are oxidised
n of the lead-oxide, a part of the lead-oxide is reduced, and a slag
ide and the oxide of the metal is produced; but the perfect oxida-
ssing little affinity for oxygen cannot be effected in this way, with-
cess of litharge.
or arsenides melted with litharge, yield sulphurous and arsenious
tilised, and alloys of the metals with lead

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Iron-sulphide melted with thirty parts by weigh
sulphurous acid being volatilised, while the iron rem
ferric oxide combined with the excess of lead-oxide
the reduced lead. With less lead-oxide the decomp
the iron-sulphide passes into the slag.

The oxidation of cuprous sulphide in this way re

The oxidation of copper pyrites requires at least
used, the copper-sulphide remaining undecomposed
sisting of lead-oxide and cuprous oxide, but forn
metallic lead.

Antimony-trisulphide is entirely decomposed b
times its weight of litharge, yielding antimonic acid

Tin-sulphide requires for perfect decomposition 8

Zinc-sulphide requires 25 pts. of litharge.

Bismuth-sulphide when melted with litharge yie
bismuth and lead, but no bismuth-oxide.

Lead-sulphide is decomposed by melting it with
the whole of the lead being separated in the met
volatilised. When the lead-sulphide is in excess, i

Arsenic-trisulphide melted with from 50 to 60 pts
yielding sulphurous acid and arsenious acid.

Other metallic oxides react with metallic sulphi
and, as a general rule, when a metallic sulphide i
former is oxidised to a greater or less extent, and
produced depends upon, 1st, the relative quantity of
chlorous and basylous characters of the metals and

Lead-carbonate acts in the same manner as lead
oxides.

Lead-silicate also acts in the same manner, but a
produce the same effects as litharge. The slags pr
cates containing both metals.

Lead-sulphate is a still more powerful oxidising
composition of its sulphuric acid yields an additiona
melted with lead-sulphide in due proportions, th
and sulphurous acid.

Cupric sulphate heated with metallic sulphide
action like lead-sulphate.

Copper-sulphide heated with cupric-sulphate i
oxide, cupric oxide, basic cupric sulphate, &c., acc
peratures. Silver-sulphide is also converted into s
tallic silver may be separated by the action of cupr

Ferrous sulphate acts in a similar manner with r

Nitrates are too costly to be generally used in m
are the most powerful oxidising agents in melting c

Basic ferrous silicate is one of the most imports
operations. For instance, when iron containing c
readily oxidable substances, is strongly heated with
of the ferrous oxide is decomposed, and the oxygen
above-named impurities of the iron, forming carbon

Solvent melting is practised chiefly with the c
the materials operated upon in the extraction of
this purpose are principally metallic oxides, silica,
metals, and sulphides.

Metallic Oxides.—Easily fusible oxides, such as
less fusible oxides, at sufficiently high temperature
less extent, sometimes forming saline compounds
solved by lead-oxide and bismuth-oxide without
termed oxysulphides. In metallurgical operation
lead-oxide which is of special importance, and that
(See p. 951.)

As a general rule, all oxides which are readil
oxides, may be mixed with lead-oxide in all propor
oxides yield with lead-oxide difficultly fusible mixt

Tin-sesquioxide dissolves in four parts by weig
liquid; with eight parts of lead-oxide it forms a ve

Zinc-oxide dissolves in seven parts of lead-oxide,

Ferric oxide dissolves in four parts of lead-oxide

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n one and a half times its weight of lead-oxide forms a very
is probably soluble to a still greater extent.
e sulphides, those of gold, silver, copper, &c., do not dissolve in
ee above). All the other sulphides are more or less dissolved
ulphide appears to be especially soluble in lead-oxide.
he metal principally used as a solvent in certain melting opera-
perty, when melted with argentiferous and auriferous sulphides
l by sufficiently intimate mixture, of dissolving out the silver
is due to the decomposition of the gold and silver sulphides
perature, in such a manner that these metals are eliminated
formed, while, at the same time, there is scarcely any decom-
de or copper-sulphide in the same way. The products of the
argentiferous or auriferous lead containing lead-sulphide, and
opper-sulphide and iron-sulphide. Gold or silver may also be
ic copper by means of lead, but in a less direct manner. Both
the copper are dissolved by the melted lead; but in the solidi-
re, the greater part of the lead separates, and there is produced a
f lead containing gold or silver, and of an alloy consisting of
s its weight of copper, containing much less silver. When this
is heated to the melting point of lead, this metal may be sepa-
he gold and silver, while the copper-lead alloy remains behind.
such as iron-sulphide, &c., may be used in the same manner as
acting gold or silver from ores or metallurgic products. Thus
aining large admixtures of gang, in the melting of which alone the
er would pass into the slag, are melted with iron-sulphides, the
sulphide, and the gangue forms a slag containing but little silver.
sed alone as a solvent in the melting operation, silicates or
present, with which it forms compound silicates. Its action in
re indirect, and depends more upon the nature of the silicate
4.)
as baryta, strontia, lime, magnesia, and alumina, respectively form
fusible or infusible compounds, according as the basylous charac-
ation to silica, is greater or less, and according to the proportions
The fusible baryta-silicates contain from 30 to 70 per cent.
infusible. Strontia-silicates are much less fusible; that containing
ms a white opaque mass. Among the lime-silicates the limits of
n 25 per cent. and 47 per cent. of lime. Magnesia-silicates, and
icates, are infusible, and soften only at a full white heat.
m compounds with silica which present similar differences in fusi-
ie greater or less basylous character of the oxide in relation to
ions in which they are combined. Thus ferrous silicates with from
rous oxide, are easily fusible, while ferric silicates are infusible.
sible only when it contains 70 per cent. cuprous oxide. Cupric
infusible, but on account of their liability to undergo reduction,
produced. Zinc-silicates and tin-silicates are infusible. Lead-
om 54 to 88 per cent. of lead-oxide melt more or less easily.
still more fusible. Antimony-silicates are sparingly fusible.
s dissolve most metallic oxides to some extent, the carbonic acid
elled at a red heat. With a sufficient excess of alkaline carbonate
unds are easily fusible (Berthier). Ferrous oxide melted with
arbonate yields a greenish crystalline mass. Ferric oxide appears
lted alkaline carbonates. Tin-oxide fuses readily with 5 pts. by
carbonate; zinc-oxide is less soluble. Cuprous oxide and cupric
h 3 pts. of potassium-carbonate. Lead-oxide mixes in all propor-
aline carbonates.
icient solvent in melting operations, but is too costly to be much
Baryta, lime, magnesia, and alumina are dissolved in considerable
d borax, forming more or less fusible vitreous masses (Berthier).
elt together with borax at high temperatures. All the metallic
reduced by heat alone, are dissolved to a greater or less extent by
ous oxide or ferroso-ferric oxide, melted with an equal weight of
et crystalline mass. Manganous oxide is dissolved in very consider-
x. Lead-oxide and borax melt together in all proportions.
rtant as a solvent in melting operations, on account of its capa-
out half its weight of silica at a high temperature, without having
bine with or dissolve metallic oxides. Fluor-spar is, therefore, a
he smelting of ores which are refractory on account of the silica they

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contain. Fluor-spar also dissolves sulphates which a
such as heavy spar, gypsum, &c. Thus with 1½ pt
calcium-sulphate, or 10 to 15 pts. lead-sulphate, flu
are tolerably fusible.

Silicates.—The earthy and alkaline silicates in
of dissolving metallic oxides in considerable pro
vitreous or stony masses generally called **slags**.
importance that there should be a proper proport
bases in the materials from which the slag is pro
solvent action upon the metallic oxides present ma
The former might be the case if there were too mu
little. Siliceous slags are generally of such compo
in the bases to that in the silica is approximatively
the nature of the silicates generally and from the
produced in metallurgical operations, it is of co
chemical compounds. Slags may indeed contain d
cases they are merely heterogeneous mixtures of
titious substances, and therefore the attempt to rep
is not only useless but deceptive. The utmost tha
to the composition of slags is, that there are certain
the fusibility, &c. of slags and the ratio of the oxy
The numerous analyses of slags from different metal
in favour of this view, and from among them the
present the general composition and limits of variat

Names of Works.	Blast furnace slags, from iron smelting.			
	Creusot.		Gesberg.	
Analyst.	Guenyveau.		Ongren.	Sjögren.
Silica . . .	39·5	49·6	58·6	61·1
Alumina . .	18·0	15·0	6·6	5·4
Ferric oxide .	3·0			
Manganous oxide	trace	. .	2·8	2·6
Ferrous oxide .	. .	3·0	1·7	3·3
Lime . . .	35·6	30·0	9·3	19·8
Magnesia . .	. .	. .	10·5	7·1
	96·1	97·6	89·5	99·3
Ratio of oxygen in bases to oxygen in silica	1 : 1	1 : 1·5		1 : 2·5

The solvent action of earthy silicates upon metall
effecting the separation of the ferrous oxide, produce
and certain products of metallurgic operations, such
a mixture of ferric oxide, cuprous oxide, and a sil
subjected to reducing melting, the cuprous oxide an
the former yielding metallic copper, and the latter
the silicate, forming a fusible slag which admits of the
collecting together in mass below it. Manganic oxide
in the same manner as ferric oxide; and any easily r
as cuprous oxide.

Silicates also exercise a solvent action upon the g
example, when an ore consisting of galena and g
ferric oxide and suitable slags, the latter dissol
reduced to ferrous oxide, which reacts with the lead
the sulphur to sulphurous acid, which volatilises, w
the same time, separates the lead from combinatio
forms iron-sulphide. In this case all the differe
operations take place together.

As a general rule it may be stated, that when m
oxide which is more easily reduced, and of silicates
silica, are subjected to reducing melting, the least
by the silicate and forms slag, while the more easily

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ever, it is necessary that the silicate should be present in suffi-
at its melting point should be higher than the temperature at
reducible oxide is decomposed, and lower than that at which the
xide is decomposed. If there were a deficiency of silicate, the
xide would not be converted into slag, and a portion of it would
llic state. If the silicate melted before the cuprous oxide had
the latter would pass into the slag; and if it did not melt till
been partly reduced, the copper would be mixed with iron.
ral be more easily fusible, or at most not less fusible than the
melting operation; but the actual degree of fusibility will vary
g to the temperature requisite in the operation. The following
ary of the more important results obtained by Plattner in his
sibility of various silicates and slags:—

Melting point.	Silica.	Baryta.	Lime.	Magnesia.	Alumina.	Ferrous oxide.	Manganous oxide	Lead xide	Ratio of oxygen in bases to oxygen in silica.
. .	29·1	70·9	. .	. .	. .	. .	. .	. .	1 : 2·1
. .	37·6	62·4	. .	. .	. .	. .	. .	. .	1 : 3
. .	52·0	. .	48·0	. .	. .	. .	. .	. .	1 : 2
. .	61·8	. .	38·2	. .	. .	. .	. .	. .	1 : 3
. .	59·8	. .	. .	40·2	. .	. .	. .	. .	1 : 2
. .	69·0	. .	. .	31·0	. .	. .	. .	. .	1 : 2·8
. .	64·3	. .	. .	. .	35·7	. .	. .	. .	1 : 2
. .	73·0	. .	. .	. .	27·0	. .	. .	. .	1 : 3·2
. .	48·6	10·0	41·4	. .	. .	. .	. .	. .	1 : 2
. .	45·0	20·0	35·0	. .	. .	. .	. .	. .	1 : 2
. .	54·0	20·0	. .	. .	26·0	. .	. .	. .	1 : 2
. .	55·5	. .	25·8	18·7	. .	. .	. .	. .	1 :
. .	40·5	. .	37·2	. .	22·3	. .	. .	. .	1 : 1
. .	57·5	. .	26·5	. .	16·0	. .	. .	. .	1 : 2
. .	30·5	. .	. .	. .	. .	69·5	. .	. .	1 : 1
. .	47·0	. .	. .	. .	. .	53·0	. .	. .	1 : 2
1431°	50·0	. .	30·0	. .	17·0	3·0	. .	. .	1 : 1·5
1445°	58·0	. .	22·0	10·0	6·0	2·0	2·0	. .	1 : 2·2
1331°	48·0	. .	4·5	1·5	9·0	37·0	. .	. .	1 : 1·75
1360°	50·0	1·5	3·0	1·5	6·0	38·0	. .	. .	1 : 2
1317°	36·5	. .	4·0	3·0	8·5	40·5	. .	7·5	1 : 1·25
1345°	32·7	. .	. .	. .	7·0	60·3	. .	. .	1 : 1

ven as those at which these silicates were formed and melted refer
of platinum 2534° C., gold 1102° C., silver 1023° C., and lead
lattner as the standards of comparison in his experiments.
differs very considerably, and it is often of great importance in
n which they solidify also is of still greater importance. Some
hange at once by reduction of temperature from the liquid to the
less liquid, and solidify gradually, passing through several stages

ontain a smaller proportion of silica than the latter; and the
ile in the melted state, and after solidification, often furnish
gist with indications as to whether the materials he is operat-
portioned or not.
s amorphous, sometimes crystalline. The former are often
nt an appearance resembling certain rocks, such as lava, and in
approximate to augite, olivin, felspar, &c.

Sublimation and Distillation.

and metallic compounds are in some cases separated from
that character. Thus arsenious acid, arsenic sulphide, and cin-
this way from other substances with which they may be mixed or
e compounds of iron with arsenic are decomposed by heat,
ic, which is volatilised, while a lower arsenide remains. Arsenical

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pyrites heated in a close vessel yields arsenic
arsenic, about half the sulphur and rather less o
the iron. When mercury ores are heated with
fixed compound with any constituent of them w
combination with the metal, metallic mercury d
mixed with carbon and exposed to a white hea
bonic acid; the carbonic-oxide produced by the p
the zinc-oxide, and the metal is volatilised.

ELIQUATION AND CRY

These operations are practised with the object
which have different melting points, or whic
Argentiferous lead is separated from a mixture
(see p. 953), by heating it in such a manner that
from the alloy of copper and lead which rem
argentiferous lead by crystallisation, since the al
of silver does not solidify until the alloy of l
separated in crystals. (See p. 504.)

The metallurgical operations already treated
heat, involve the use of fuel as a source of heat
importance to apply it to this purpose in the m
The general principle by which the relative va
determined, and the conditions under which th
have been already considered. (See FUEL, ii. 718
simply to the means of augmenting the efficacy o
far as relates to the production of high temperat
in the combustion of fuel. The advantage ga
consumption of a proportionately larger amou
temperature produced; but since the metallurgi
temperature can be conducted much more rapidl
increased, the saving of fuel effected by using a
larger quantity of material which can be worke
what can be worked within the same time at a lo

Whenever it is necessary to use fuel in such
heating power is rendered effective, as in most
manufacture of iron, a very great economy can b
the purpose of heating the air with which the
those gases to escape without producing any usef
to the air with which the furnaces are fed has
produced in those furnaces to a degree far highe
combustion of the fuel used. This augmentatio
tionate to the increased temperature at which air
the production of a very high temperature is the
of fuel is to be attained in the manufacture of i
are of the highest importance. (See IRON, iii. 3

In many metallurgic operations, the use of gase
so as to convert it into carbonic oxide and hydroc
very valuable means of effecting economy in fuel,
advantageous results as regards the metals produc
made in this direction compared with the capabil

The use of air containing a larger amount of o
be a very efficient means of economising fuel, e
temperatures or intensity rather than quantity o
been made to realise the advantages of such a
been attended with any such success in relation
to require more than a passing mention. (See

The metallurgic operations which are conducte
ture, and by the agency of water or other solve
wet way, are but few, viz. the extraction of platin
from silver, and to a less extent the extraction o

SOLUTION AND PERC

By the first of these operations silver is extrac
means of a solution of sodium-chloride, after the

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also extracted from its ores by means of nitro-hydrochloric acid, and rom gold by treatment with nitro-hydrochloric acid, which dissolves l; or when the silver amounts to more than three times as of nitric acid (see GOLD, ii. 925), which dissolves only the silver, g termed parting. Copper is also extracted from poor ores by hloride or sulphate, and dissolving these salts out with water. (See

n involving solution is the extraction of gold and silver from their ercury, which is frequently practised under the name of amalga- solution of the metals by mercury depends upon the formation of dissolves in excess of mercury. (See GOLD, ii. 925, and SILVER.) is practised for the separation of metals from the solutions obtained mentioned. Thus copper is precipitated in the metallic state by on, which decomposes the copper-compound held in solution. This l *cementation*. (See COPPER, ii. 36.) Platinum is separated from nio-chloride, by precipitation with solution of sal-ammoniac; , by means of solution with salt, or hydrochloric acid; and gold, in by means of ferrous sulphate. (See GOLD, ii. 925.)

ations of metallurgy which are conducted by means of electrolysis, ating, electrogilding, and electrotyping, depend upon the ve already been discussed in general terms in the article ELECTRICITY 437); and more precise details will be found in *Ure's Dictionary of , and Mines*, article ELECTRO-METALLURGY.

anufacturing aluminium, magnesium and sodium, &c., will be s devoted to the general chemistry of those metals. B. H. P.

TOMIC WEIGHTS AND CLASSIFICATION OF.

d metals.—The received atomic weights of the non-metallic hlorine, bromine, and iodine, or 19, 35·5, 80, and 127, are merely of each of them which have the same gaseous bulk as the unit of four halogen elements, which may be considered as chlorous or elec- ies of hydrogen, have the characteristic property of replacing nother, in a great variety of compounds, by an equivalent substitu- olume, atom for atom. The fluoride, chloride, bromide, and iodide mposed of equal volumes of halogen and hydrogen united without olume or atom of chlorine, for instance, uniting with one volume or o form two volumes of hydrochloric acid, HCl. These two volumes ecule of hydrochloric acid, which is usually regarded as a chloro- olecule of hydrogen, HH, and taken as a convenient standard of -volume molecules in general.

ium, sodium, potassium, rubidium, cæsium, and silver e above halogen elements, and accordingly may be looked upon as -positive varieties of hydrogen. Their received atomic weights, K 39, Rb 85, Cs 133, and Ag 108, express the relative quantities of can displace 1 part by weight of hydrogen to unite with 35·5 parts ne. Now it is found by experiment that 7 parts of lithium, 23 parts of potassium, and 108 parts of silver have substantially the as one another; so that 7 parts of lithium and 108 parts of silver, b or evolve the same amount of heat in undergoing the same ment of temperature. The specific heats of the atomic proportions , and by analogy of rubidium and cæsium also, are moreover sub- with the specific heats of the atomic proportions of chlorine, , and may be expressed with sufficient accuracy for our present mber 6·2, in comparison with the specific heat of water taken as ity. Each of these metals unites with chlorine in but a single to form a chloride expressible by the general formula M'Cl, de- pe HCl; and the specific heats of these several chlorides and of romides and iodides, approximate to the number 12·4, giving a for each atom in the molecule.

he monad metals, though more or less volatile at high tempera- iently so to allow of their densities in the vaporous state being riment. Their theoretical vapour-densities, however, are assumed heir respective atomic weights, and their molecules are accordingly al two-volume standard. One or two of these metals, more parti- sodium, have been made to combine with the organic radicles but the resulting methides and ethides have not been obtained in n, and *à fortiori* have not had their vapour-densities determined.

is group have the common property of forming sulphates which

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combine with sulphate of aluminium to produce
hydrated double salts, crystallising in octahedrons,
the alums. They are also distinguished by their ca
salts of dibasic acids, and incapability of forming b
acids, properties, however, which appertain to silv
metals potassium, rubidium, and cæsium form a de
special properties. They are the most powerfully
elements, and the intensity of their basylity increa
weights. Their hydrates and sulphydrates are ver
fully caustic solutions. Their carbonates also ar
caustic compounds. Their chlorides are deliques
sparingly soluble, and their platino-chlorides and
Sodium is far less basylous than potassium, and lit
oxidisability of sodium is well shown by its want
caustic soda, and by the facility with which it is
operations of modern metallurgy. Its hydrate ar
potassium, but its carbonate is efflorescent, very mo
caustic; while carbonate of lithium is almost insolu
like the carbonates and phosphates of the alkali-ea
bonate of potassium is perfectly fixed in the fire,
proportion, and carbonate of lithium a considerable
and again, the solution of chloride of lithium, thou
chloride of magnesium, is decomposed during eva
acid. Silver, although distinguished from most of
neutrality of its soluble salts, differs from the alkali-
gravity, its permanence in air, the insolubility
indifference of its oxide and sulphide to the action of
to be a relationship between sodium and silver mani
anhydrous sulphates, and in other ways. Bearing i
the specific gravities of allied metals increase in the
superior specific gravity of sodium over that of pota
having a latent association with the heavy metals. Th
addition to their characteristic trichlorides, form pr
specific heats, insolubility, and general properties
chloride of silver, whence the metals themselves ma
time monatomic and triatomic.

Group II.—Dyad Metals; namely, glucinum
tium, barium, zinc, cadmium, and mercury
with those last considered in being more or less
them in a variety of other particulars. Of glucinum
unascertained properties will be assumed to corre
properties of magnesium. With the exception of
normal chloride, or corrosive sublimate, forms an infe
out of consideration for the present, all the member
in a single proportion only. With the atomic we
metals, their chlorides would be represented as pro
M'Cl corresponding to HCl; but doubling their re
cated more particularly by Wurtz and Cannizzaro
sented as dichlorides, by the general formula M"Cl
below:

		HCl
G	4·5	*G*Cl
Mg	12	*Mg*Cl
Ca	20	*Ca*Cl
Sr	43·75	*Sr*Cl
Ba	68·5	*Ba*Cl
Zn	32·5	*Zn*Cl
Cd	56	*Cd*Cl
Hg	100	*Hg*Cl

Several metals not belonging to this group form
tabulated, just as the triad metals thallium and gol
protochloride of silver. The disputed formulæ of a
sake of illustration:—

Cu	31·75	*Cu*Cl
Sn	59	*Sn*Cl
Pb	103·5	*Pb*Cl

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inciples on which the determination of atomic weights must logically
cussed very fully in a previous article (*vide* ATOMIC WEIGHTS), which it
was necessarily written long before the date of its publication. It
d, that although in the author's opinion, the arguments in favour of
ic weights of the metals now under consideration, were not at that time
t to warrant the adoption of a hasty change in old established usages,
osal being then of very recent introduction, it was not improbable that in
objections to which it was liable would be more or less satisfactorily ex-
ile further potential arguments might possibly be adduced in its support.
has since actually taken place; for although the objections to the pro-
n now be regarded as altogether overcome, yet the arguments in its
rate so largely as to leave no doubt whatever about the ultimate
adoption. Before considering *seriatim* the reasons for and against
ubling of the atomic weights of these metals, it may be observed
, just as there are monatomic, diatomic, and triatomic chlorous
ld we expect to have monatomic, diatomic, and triatomic basylous
ls. It would, moreover, be extremely strange if while triad and tetrad
antly met with, there should exist only one or two well-known dyad
ust as among chlorous elements, the distinction between monatomic
ms was recognised long before the distinction between monatomic and
o is it natural that among basylous elements also, the distinction
ic and diatomic metals now proposed for adoption, should not be
long after the distinction between monad and triad metals had been
ly acknowledged.

eat.—If we represent the chlorides tabulated above, as dichlorides,
proportions of metal combined with two atoms of chlorine in their
les have their specific heats expressed by the number 6·2, just as have the
s of metal united with one atom of chlorine in undisputed protochlorides,
roportions of metal united with three atoms of chlorine in undisputed
t if we continue to regard the chlorides in question as protochlorides,
f metal contained in their respective molecules will have only half the
e proportions of metal contained in the molecules of undisputed proto-
In other words, with the doubled weights and formulæ, the atoms
metals will have the same specific heats, whereas with the old atomic
l have only half the specific heats, of the atoms of chlorous dyads,
and selenium; of chlorous and basylous monads, such as bromine,
nd silver; and of chlorous and basylous triads, such as phosphorus,
, and gold. Moreover the specific heats of their respective chlorides,
ichlorides, will agree with the specific heats of undisputed proto- and
his particular, that, divided by the number of atoms in the molecule,
ld the constant 6·2. Thus the ascertained specific heat of corrosive
(200 + 35·5 × 2) is 18·67, which divided by 3, gives the quotient 6·22.
—The argument from atomic heat is admitted to have great force,
fficient to be absolutely decisive of the question, inasmuch as the ato-
non-metals, boron, carbon, and silicon, are not under any circumstances
s great as the atomic heats of their metallic congeners. It being
ible to accord the same specific heats to the atoms of all the elements, it
able that the atomic heat of certain metals should differ from the
the remainder, that magnesium and mercury, for instance, should
ie atomic heat of sodium and silver. Then the molecule of chloride
l, for instance, would have the specific heat of its constituent atoms,
hile the molecule of chloride of silver AgCl, would have the specific
tuent atoms, 6·2 + 6·2 = 12·4.

ar Volume.—Mercuric chloride and mercuric ethide, if represented
e formulæ $HgCl^2$ and $HgEt^2$ respectively, have the same molecular
corresponding monadic compounds, hydric chloride HCl, and hydric
ectively, and as the corresponding triadic compounds, arsenic chloride
ic ethide $AsEt^3$ respectively. The gaseous volumes of zinc-chloride
loride have not been ascertained, but the gaseous volumes of their
hides and methides agree with the ethide and methide of mercury, in
of their respective vapour-densities being the halves of their atomic
ey are represented as dyadic compounds, thus:

2 vols.	2 vols.	2 vols.
H Cl	$Hg''Cl^2$	$As'''Cl^3$
HEt	$Hg''Et^2$	$As'''Et^3$
EtCl	$Zn''Et^2$	$B'''Cl^3$
	$Sn''Et^2$	$B'''Et^3$

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In other words, the volatile chlorides and ethides o dyadic, will have the same molecular volume, whereas will have only half the molecular volume of undisputed protethides and triethides, &c.

Objection.—The above argument from molecula rather less weight than that from atomic heat: for by and its congeners the formulæ which bring their m with the molecular volumes of chloride of hydrogen, forced to accord to the metals themselves, molecul with the molecular volumes of the elements, hydroge

2 vols.	2 vols.
HCl	H^2O''
HEt	Et^2O''
EtCl	Cl^2S''
HH	OO
ClCl	S S
BrBr	SeSe

In other words, the proportions of mercury, of cad which combine with two atoms of chlorine, or eth gaseous volume of the proportion of hydrogen whi chlorine, or ethyl, or methyl, and consequently doubl of oxygen and sulphur respectively which combin proportion of nitrogen which combines with three methyl. But just as the diatomic chlorous elements same gaseous volume as, and not double the volu elements, chlorine and bromine, so should we expect mercury and cadmium, to have the same volume as, the monatomic basylous metalloïd, hydrogen. This by comparing the molecules of mercury, cadmium, &c oxygen, free sulphur, &c., which are divisible in the molecules of the diatomic compound radicles carbo ethylene, &c., which are indivisible; thus:—

2 vols.	2 vols.
$H^{\prime 2}$	Hg''
$Cl^{\prime 2}$	Cd''
$O^{\prime\prime 2}$	$(CO)''$
$S^{\prime\prime 2}$	$(SO^2)''$
$Se^{\prime\prime 2}$	$(C^2H^4)''$
$N^{\prime\prime\prime 2}$	$(C^6H^6)''$

Whatever value may be accorded to this explanat discordance undoubtedly remains, that the atomic pr mercury and cadmium, have double the volume of sulphur.

γ. Double Salts.—The characteristic property lity, when united with one and the same monaton radicle by two successive substitutions, and of the monatomic radicles. Now this property of combini certainly very well exemplified by the class of metal as shown in the list of compounds tabulated below, w

$(Hg\mathrm{Cl})^2$	Mercury, dichloride
$Hg\mathrm{Cl}.Hg\mathrm{Et}$	„ chlor-ethid
$(Hg\mathrm{Et})^2$	„ diethide
$Hg\mathrm{Et}.Hg\mathrm{Me}$?	„ etho-methi
$Zn\mathrm{Et}.Zn\mathrm{I}$	Zinc iodo-ethide
$Ca\mathrm{Cl}.Ca\mathrm{ClO}$	Bleaching powder
$Sr\mathrm{NO}^3.Sr\mathrm{C}^2\mathrm{H}^3\mathrm{O}^2$	Strontium acetato-nit
$Ba\mathrm{NO}^3.Ba\mathrm{C}^2\mathrm{H}^3\mathrm{O}^2$	Barium acetato-nitra
$Cu\mathrm{HO}.Cu\mathrm{F}$	Copper, fluo-hydrate
$Pb\mathrm{HO}.Pb\mathrm{NO}^3$	Lead, hydrato-nitrat
$Pb\mathrm{HO}.Pb\mathrm{C}^2\mathrm{H}^3\mathrm{O}^2$	„ hydrato-acetat

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ber of these double compounds possess a moderate degree of sta- of them, as the double halogen ethides and methides, are among and stable of metallic salts. The relation of the organic compounds rsenic to one another is evidently parallel to that of alcohol and amines, as shown below:

s.	Dyads.		Monads.	
Cl^3As	H^2O	Cl^2Hg	HCl	ClNa
$EtCl^2As$	EtHO	EtClHg	EtCl	EtNa
Et^2ClAs	Et^2O	Et^2Hg		
Et^3As				

alcohol, the basylous radicles, hydrogen and ethyl, are held together n, so in the hydrato-nitrate of lead, the two chlorous radicles are iatomic lead (Williamson, Chem. Soc. J. xvii. 211). Accordingly, place diatomic oxygen by monatomic chlorine, we get two distinct

$$PCl^3Cl^2 + HEtO'' = PCl^3O'' + HCl + EtCl.$$

in our lead-salt we replace diatomic lead by monatomic silver, we rgentides, thus:

$$g^2 + HO.NO^2Pb'' = SO^4Pb'' + HOAg + NO^2Ag.$$

-The force of this argument is much diminished by remembering ubted monatomic elements and groupings have the property, though t, of combining with two distinct monatomic radicles. Chlor-ethide nstance, Hg″EtCl, may be written $(Hg^2)EtCl$, and compared with ilver, $(Ag^2)I.NO^3$, argento-chloride of sodium, $(Cl^2)AgNa$, hydro- ium, $(F^2)HK$, hydro-acetate of potassium, $(2C^2H^3O^2)HK$, and many s, in which we have the monatomic elements silver, chlorine, fluorine, sic acetic acid, &c., combined with two different monatomic radicles, the stability of these compounds, save and except some of the hydro- very feeble character. Moreover, in contrasting the properties of and diatomic ethylene, and comparing the undisputed monad metals nd the metals under discussion with the latter, there is one point, at e importance in which the comparison does not hold good. The ibasic acid is found to be replaceable by two different monatomic he same radicle at two successive stages, whereas it is replaceable by c radicle only, and that at a single operation. Thus the diatomic nay be substituted for the hydrogen of oxalic acid to form oxalate of C^2O^4, which is the only derived oxalate of ethylene hitherto known; natomic radicle ethyl we have acid oxalate of ethyl, $(C^2H^5)'HC^2O^4$, f ethyl, $(C^2H^5)^2C^2O^4$, potassic oxalate of ethyl, $(C^2H^5)KC^2O^4$, &c. In monatomic radicle ethyl does, and the diatomic radicle ethylene does nd double ethers or salts of dibasic acids; and a similar difference of ifested by monatomic and diatomic chlorous radicles, such as acetyl lyl $(C^2O^2)''$, in their relation to a diacid base such as glycol. Now oes not seem to be any decided difference in this particular between of metals. One member, at any rate, of the first group—namely, or scarcely does, while several of the members of the second group form well-defined acid and double salts, as exemplified by the acid m, $BaHC^2O^4$, potassio-oxalate of zinc, $ZnKC^2O^4$, acid carbonate of HCO^3, gay-lussite, $CaNaCO^3$, dolomite, $MgCaCO^3$, acid sulphate of auberite, $CaNaSO^6$, acid selenite of calcium, $CaHSeO^3$. &c. &c. Such novinates of calcium and barium cannot properly be adduced in illus- although for some purposes, sulphovinic acid may be regarded as a of ethyl and hydrogen, comparable with acid sulphate of potassium, y a conjugated compound analogous to the sulphamic and sulpho- instance, and consequently as much monobasic as the formic, acetic, themselves.

ever, be contended in any way that the property of forming acid and n dibasic acids is incompatible with the diatomic character of the em; for, indeed, there is no sufficient reason why the atom of a dyad bind together two atoms of dibasic sulphuric acid, for instance, just e diatomic radicle sulphuryl binds together two atoms of dihydric

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$$\left.\begin{matrix}H\\H\\H\\H\end{matrix}\right\}O \qquad \left.\begin{matrix}H\\(SO^2)''\\H\end{matrix}\right\}O$$

The utmost that can be said is, that t
and ethyl in their behaviour with dil
difference of properties manifested und
groups of metals.

δ. Basic salts.—A well-marked
radicles, which has been pointed o
special tendency which the oxides of
have, to produce basic and anhydro-s
which they have of accumulating in c
containing multiple radicles, and belon
Thus we are acquainted with potassic
dichromate, $K^2O(CrO^2.O)^2$, and potass
we have monethylenic glycol, $(C^2H^4$
ethylenic glycol, $(C^2H^4.O)^3.H^2O$, and
distinction, unlike those hitherto cons
observe that diatomic oxides do, an
accumulate in the manner above ex
difference of behaviour should result
On this account therefore, that it is
deducible from difference of constitut
to this last distinction as to those whic
time, the different habit of monatomic
well marked. We are acquainted, f
and acetates of ethylene, but with no su
The question consequently arises, whe
leged diatomic and the undisputed mon
ence does exist, is certainly, so far as
now under consideration. Thus we c
acetates, &c. of ethylene by similar
copper, &c., but not by any compound
for example, Schaffner's hydrate of
$H^2O(PbO)^3$; Mendipite, $PbCl^2.(PbO)^3$
ride of zinc, $ZnCl^2(ZnO)^3.2H^2O$; Rose's
dromagnesite, $(MgCO^3.H^2O)^3.MgH^2O^2$
dibasic acetate of lead, $C^4H^6PbO^4.PbO.$
tribasic acetate of lead, $C^4H^6PbO^4(Pb$
cury, $HgN^2O^6.HgO.2H^2O$, &c. &c. T
observation of Wurtz, to the effect tha
diatomic, we are able to express the si
instead of with half atoms of water
among many other examples: aceta
$C\ H^6PbO^4.3H^2O$; perchlorate of lead,
chloride of nickel, $NiCl^2.9H^2O$, &c.

Objections.—It is contended th
tion is not necessarily but only ac
that, just as the acetic and iod
$(C^2H^3KO^2)^2.C^4H^6O^3$ and $KIO^3.I^2O^5$,
may the plumbic and cupric base-oxi
monatomicity. From several consid
acid $C^4H^8O^4$, and a trihydric iodic aci
anhydro-acetates and anhydro-iodates
forms of their respective acids. As f
by itself, it certainly cannot lay claim
obvious reason why one atom of wate
H^2O with $(C^2H^3CuO^2)^2$ for instance, th
to combine with two or three atoms o

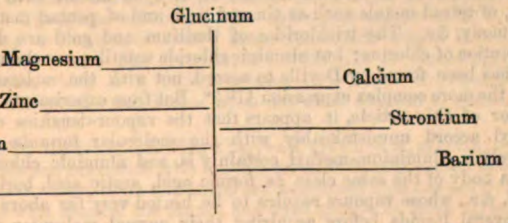
But although the arguments in favo
as dyadic, when taken separately, are
taken altogether, they seem to present
of the proposal, as to render its adopti
conclusion, then, as inevitable, and ac
previously received atomic weights, w

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etween them and the already considered nomad metals, as shown

G″ 9		
Mg″ 24	K′ 39	Ca″ 40
Zn″ 65	Rb′ 85	Sr″ 87·5
Cd″ 112	Cs′	Ba″ 137
Hg″ 200		

e alkaline-earth sub-group, namely, calcium, strontium, and barium, sylous or oxydisable than those of the alkalis, and the degree of ncreases in the order of their atomic weights. Their hydrates and those of the alkali-metals, are soluble in water, forming caustic sorb carbonic anhydride with great avidity, to form, however, inso- and their sulphates are likewise insoluble. Among the members of , the manifestation of metallic properties, as popularly understood, lous characters, increases in the order of their atomic weights; and regard the upper members of each sub-group as exhibiting a very the lower members as exhibiting highly specialised forms of the and may figure the difference to ourselves in some such diagram as



he less basylous or more reguline sub-group are distinguished by nich increases in the order of their several atomic weights. The metals are insoluble in water, and only those of glucinum and mag- uch affinity for carbonic anhydride. The sulphides of zinc, cadmium, insoluble permanent precipitates, while that of magnesium also oluble in, though readily decomposible by water. Their sulphates, e more basylous dyads, are all soluble in water, with the exception rcury, which is decomposed thereby into sulphuric acid and a basic ints of its behaviour, magnesium presents a general resemblance to t one time classified with the alkaline-earth metals.

corrosive sublimate, $HgCl^2$, mercury forms an inferior chloride, or olecule may be represented by the formula HgCl, corresponding to ide of silver, AgCl, or by the formula Hg^2Cl^2, corresponding to that of hur S^2Cl^2; and the selection of one or other of these expressions will e the entire series of formulæ to be accorded to the entire series of The formula HgCl, by which calomel is represented as a proto- rosum, is recommended by its superior simplicity, by the ready ercurous salts to double decomposition without change of type, by calomel to the insoluble monad chlorides of silver, gold, &c., and ion of its vapour-density, which is found to be $\frac{200+35\cdot5}{2} = 117\cdot75$; s of calomel vapour, HgCl, contain one volume of chlorine, just as two hloric acid, HCl, contain one volume of chlorine. On the other hand, ^{2} is recommended by its consistency with the law of even numbers, hat a dyad element can never unite with an uneven number of with the frequent spontaneous decomposition of mercurous salts into mercury, $Hg^2Cl^2 = HgCl^2 + Hg$. Moreover, the existence of several mpounds is opposed to the representation of normal mercurous com- lts; while the discordance in molecular volume between calomel and lphur, as revealed by the determination of their vapour-densities ile $Hg^2Cl^2 = 4$ vols.), may be explained by supposing that the vapour t of many other salts, undergoes what is known as dissociation (i. 469; olumes of mercuric chloride, $HgCl^2$, and two volumes of mercury, ition is to some extent warranted by the observation that calomel es gold leaf, and that corrosive sublimate may be detected in re- (Chem. Soc. J. xvii. 421).

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GROUP III. Triad Metals.—Classifying the me
atomicities, there are four triad metals properly s
thallium, indium, and gold: for the trichlorides
must be regarded as the inferior chlorides of pentad, jus
and gold are the inferior chlorides of triad elements.
$TlCl^3$, and the atomic weight for thallium, 203, have
Auric chloride was formerly represented as a sesquich
atomic weight of gold being taken as 98; but it is
chloride by the formula $AuCl^3$, the atomic weight o
The old sesquiatomic formula for aluminic chloride,
the atomic weight of aluminium was taken as 13·75,
rational grounds. It is admitted on all hands t
aluminium found to exist in any definite compou
proportion is indivisible or atomic throughout all th
pounds undergo. Evidently, therefore, it ought to
atomic by the symbol Al''', and not as dipartite b
triadic, with the atomic weights 27·5, 203, and 196
the specific heats of the atoms of aluminium, thalli
number 6·2, and are accordingly identical with the
monad metals, such as sodium and silver, of dyad
mercury, of tetrad metals such as tin and lead, and o
and antimony, &c. The trichlorides of thallium a
with evolution of chlorine; but aluminic chloride vola
density has been found by Deville to accord, not wit
but with the more complex expression Al^2Cl^6. But fro
the author of this article, it appears that the vapo
and ethyl accord unmistakeably with the molecu
respectively. Aluminium-methyl certainly is, and s
may be, a body of the same class as formic acid, ac
selenium, &c., whose vapours require to be heated v
of the several liquids before acquiring their norm
220° and all superior temperatures, the corrected
methyl is perfectly constant, and accords with the f
its corrected density increases at a very rapid rate, s
130°, which high density would of course accord a
Al^2Me^6. Bearing in mind, however, the rule deducib
of Deville and Cahours, that the molecular formula o
its permanent or ultimate, and not from its variabl
having regard also to the ascertained behaviour of th
only observed vapour-density of aluminic chloride c
regarded as affording decisive evidence in favour
latter formula were established, aluminium would ha

its chloride would be represented by the constitutions

valent atoms of aluminium forming a sexvalent gro
in the molecule of hydride of ethyl C^2H^6. On t
would be represented by such formulæ as $K^2(Al$
whereas if aluminium be regarded as trivalent, the
formulæ like $KAl'''(SO^4)^2$ derived from $2H^2SO^4$. B
position or the chemical character of these salts, or
compounds, to enable us to decide positively one
character of aluminium receives, however, some sup
certain aluminic compounds present a marked re
properties to similar undoubted triatomic compounds
and antimony, for instance. Boron would seem to s
same relation as that in which lithium stands to s
sium. In each pair of elements the basylity of the
first term; while the monadic are more basylous tha
these again more basylous than the correspondin
aluminic hydrates alike act either as feeble acids or
borate and aluminate of magnesium, or boracite and
a considerable range of composition, are referrible t
and $MgAl^2O^4$, respectively. As before remarked, how
of boron is anomalous.

Thallium would appear to occupy among the triad

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g the dyads; but the position of gold in this group, whatever that is without obvious parallel. In addition to their trichlorides, &c., d each form a protochloride and a well-defined series of monad salts. f several of the monad salts of thallium to the corresponding com- ium is very marked. Thus its chloride produces an insoluble double e of platinum; its acid tartrate occurs as a crystalline precipitate; its ith sulphate of aluminium a well characterised alum; while its hydrate in water, forming a caustic solution which absorbs carbonic anhydride the other hand, protosulphide of thallium, like that of silver, constitutes ecipitate. Again, protochloride of thallium, though more soluble in eral resemblance to chloride of silver, while the protobromides and o metals present even a greater degree of similarity. The most stable lts of gold is the soluble crystalline sodio-sulphide, $AuNaS.4H^2O$. very unstable, and the protochloride is known only as an insoluble

h was discovered by Reich and Richter in 1863, and is especially the two indigo-blue bands appearing in its spectrum, is a very soft ermanent in air and water, and having a specific gravity of about 7·2. carbonate constitute white precipitates, and its sulphide a yellow ble in acetic, but soluble in mineral acids, while its chloride may be hite crystalline sublimate. Its equivalent weight is 37·8, and its rding to Bunsen, is 0·057: hence its atomic weight is $3 \times 37{\cdot}8$ or $\times 0{\cdot}057 = 6{\cdot}5$. The formula of its chloride is accordingly $InCl^3$, oxide, which is a salifiable base, In^2O^3, &c. It belongs to the of the metals, and bears much the same relation to thallium that

etrad Metals; including tin, lead, titanium, zirconium, tho-

metals are associated with the non-metallic tetrads carbon and silicon, lements aluminium and boron are associated with one another. The gree with those of the monad and dyad groups in being divisible into y reguline, and a more especially basylous sub-group, the lower of which possess the respective distinctive characters of the sub- reatest intensity. The relations of the members of the first five ther is shown in the following table:—

	Dyads.		Triads.		Tetrad		Pentads.	
	Gl	9	Bo	11	C	12	N	14
	Mg	24	Al	27·5	Si	28	P	31
	Zn	65	„	. .	„	. .	As	75
	Cd	112	„	. .	Sn	118	Sb	122
	Hg	200	Tl	203	Pb	207	Bi	210
	Ca	40	„	. .	Ti	48	„	. .
	Sr	87·5	„	. .	Zr	89·5	„	. .
	Ba	137	„	. .	„	. .	„	. .
					Th	231		

ic character of marsh gas has been recognised from almost the rganic chemistry, but the now received formula CH^4, in which the ted as indivisible or atomic, was first introduced by Gerhardt in he previously employed formula C^2H^4, in which the carbon was un- sented as dipartite. The tetratomicity of tin and silicon was first author in 1857 and the following years (Phil. Mag. xiii. 434, ep. Brit. Assoc. 1858, p. 58), and was definitively established by the es of Cahours on the stannethyls in 1860 (Ann. Ch. Phys. [3] lviii. and Crafts on the organic compounds of silicon (Bull. Soc. Chim. he tetratomicity of titanium and zirconium follows as a matter of bserved vapour-densities of their chlorides, and similarly that of pour-density of its ethylide, though it is believed that this is the which lead has been definitely classified as a tetratomic element, th tin rather than with calcium. The chlorides of carbon, silicon, zirconium, represented as tetrachlorides by the general formula thylides of silicon, tin, and lead, represented by the general formula

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M""Et⁴, have vapour-densities which are the hal
weights, and accordingly have the same molecula
hydrogen HCl, the dichloride of mercury $HgCl^2$,
$AlEt^3$, &c. Moreover, the chlorine of the chlor
especially of tin, is found to be experimentally rep
Thus, we have $SnCl^4$, $SnCl^3Et$, $SnCl^2Et^2$, $SnClEt^3$
CCl^3H, CCl^2H^2, $CClH^3$, and CH^4, respectively, a
atomic weights 118 and 207, the metals tin and
which is expressed more or less closely by the num
other metals of this group have not been ascertain
and silicon among the tetrad elements, like that
must, according to our present imperfect knowled
anomalous.

Tetrachloride of tin is a colourless fuming liq
form a series of crystalline soluble salts. Tetrachl
form of hydrated crystals. It is made by treatin
aqueous hydrochloric acid, when solution takes p
evaporation in vacuo, crystals of the tetrachloride
dichloride of lead. The solutions of the tetrachlori
by alkalis, with precipitation of the respective per
gen, with precipitation of the respective persulphid
latter of an orange-red colour. The dichlorides of
dentally referred to when discussing the dyad m
solids, whose solutions, like those of the tetrachloric
precipitation of their respective protoxides, and by
pitation of their respective protosulphides, the form
of a black colour. It may be here observed that
sulphides, not readily decomposed by water, constitu
between the reguline and alkaligenous sub-groups o
primary groups, this property being manifested b
thallium, tin, lead, arsenic, antimony and bismuth,
bidium, calcium, strontium, barium, titanium, zirco
metals yttrium, cerium, lanthanum, and didymium,
more particularly. Many of the dyad salts of m
marked resemblance in properties to the similar sa
are frequently isomorphous with them, just as the
correspond with the similar salts of potassium.
special characteristic of lead, and one strongly
consists in its very marked tendency to form doub
atomic radicles. Lead differs also from its congene
basylity, or power of neutralising even feeble acids
them results from the superior stability of the di-s
metal, and of the tetra-salts over the di-salts of th

The less reguline sub-group of tetrad metals,
thorinum, are associated with silicon and tin by
and artificial thorina, ThO^2, with native tinst
Chydenius, Pogg. Ann. cx. 642), and by th
zirconic chlorides, $TiCl^4$ and $ZrCl^4$, correspondin
$SnCl^4$. The sulphides of titanium, zirconium a
in the moist way. Their oxides are hard crystal
nary acids, save the hydrofluoric. Their hydrate
pitates, which dissolve readily in acids, to form mor
hydrates of the dyad alkaline-earth metals, $M''H^2O^2$
those of the monad alkali-metals, so should we expe
triad earth-metals, $M''''H^3O^3$, to be less soluble and ba
and the hydrates of the non-reguline tetrad metals
$-H^2O$), to be still less so. In other words, we s
sub-group of tetrad metals we are now consideri
basylity, more especially in the superior members
degree of basylity habitually increases in the order
secutive metals. We accordingly find that the char
as much acid as alkaline, though we are nevert
nitrates, phosphates and even a potassio-carbonate
zirconia is far better marked. Its silicate constitut
by precipitation; its sulphate is a soluble crystallin
is thrown down as a crystalline precipitate on mixi
phates of potassium and zirconium. Thorinum forn

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a potassio-sulphate corresponding to that of zirconium in its character mation. Moreover, hydrated thorina is sufficiently basylous to expel al-ammoniac, and to absorb carbonic anhydride from the atmosphere.

trium, erbium, cerium, lanthanum, and didymium possess the ties in common with one another and with thorinum:—Their hydrates ious precipitates, which expel ammonia from sal-ammoniac solution, onic anhydride from the atmosphere. Their sulphides are not pro- oist way, and their sulphates are precipitated by sulphate of potassium rystalline double salts. The equivalent weights of these four metals, pt. of hydrogen to unite with 35·5 pts. of chlorine, are Y 32, Eb = 56·3, d Di 48, but what their atomic weights are is altogether undecided. ate of knowledge, their extreme basylity cannot any longer be regarded ith their di-, tri-, or even tetratomicity, and there are some points in f didymium, at any rate, which are suggestive of its being a triad n is distinguished from lanthanum and didymium, as well as from acility with which it forms a superior and feebly salifiable oxide.

entad Metals.—These are six in number, namely arsenic, anti- h, vanadium, niobium, and tantalum; they are associated with nitrogen and phosphorus, just as the tetrad metals tin and lead are he non-metallic tetrads carbon and silicon. Although the pentatomicity of these elements is very well established, as shown by the phosphoric , for instance, and their corresponding chlorides and oxides, as formu- it must be admitted that their more general and characteristic beha-

Cl^5	$\left.\begin{matrix}P^v\\H'\end{matrix}\right\}O''^3$	$\left.\begin{matrix}P^v\\H^3\end{matrix}\right\}O''^4$	$\left.\begin{matrix}P^v\\P^v\end{matrix}\right\}O''^5$
Et^3Cl^2	$\left.\begin{matrix}As^v\\H'\end{matrix}\right\}O''^3$	$\left.\begin{matrix}As^v\\H^3\end{matrix}\right\}O''^4$	$\left.\begin{matrix}As^v\\As^v\end{matrix}\right\}O''^5$

oreover, these elements form monad compounds. Thus, Griess has variety of organic bodies, a single atom of nitrogen may be substituted r 3 atoms of hydrogen. Phosphorus and its associated metals were nted by atomic weights, the halves of those now universally adopted, thin a very few years that the habit of writing the antimonious and rides as sesquichlorides by the formulæ Sb^2Cl^3 and Bi^2Cl^3, respectively, tely abandoned; nor indeed is it very long since chloride of bismuth epresented as a protochloride by the formula BiCl. It is only, how- omic weights now employed, namely, P 31, As 75, Sb 122, and Bi 210, f the four elements have approximately the standard specific heat of c gravity of nitrogen gas being identical with its atomic weight, or its molecular weight, the two-volume molecule of nitrogen is repre- ression $N'''N'''$, just as that of oxygen is represented by $O''O''$, and that of I′. Deville, however, has shown that the vapour-densities of phosphorus he doubles of their respective atomic weights, and that these densities are unalterable by any increase of temperature, so that the two-volume sphorus and arsenic have to be represented by the expressions P^4 and n has very plausibly suggested that, while the molecule of nitrogen as ammonia, $N'''H'^3$, in which the three atoms of monatomic hydrogen ne atom of triatomic nitrogen, $N'''N'''$, the molecules of phosphorus and egarded as phosphine and arsine, $P'''H'^3$ and $As'''H'^3$, in which the nonatomic hydrogen are replaced by three atoms of monatomic phos- natomic arsenic respectively, $P'''P'^3$ and $As'''As'^3$. They may also by formulæ in which each of the atoms of phosphorus or arsenic

$$P\equiv P$$

g. || | ||. Except that bismuth does not form a trihydride, the $$P\equiv P$$

les, triethylides, and trichlorides of these five elements all form two- s, while the hydrogen, ethyl, and chlorine of the respective compounds aceable in thirds at three successive stages. The majority of the ds dissociate or decompose at or below their boiling points; but the ic acid $N^vH'O''^3$, oxychloride of phosphorus $P^vCl'^3O''$, oxy-ethylstibine &c., have vapour-densities which are the halves of their atomic ordingly correspond with the normal two-volume standard. Arsenic, ismuth differ from the majority of the metals in being destitute of enacity, and are therefore very commonly described as brittle or semi- eguline character is, however, very well marked, and their sulphides

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are easily formed by precipitation. The permanenti
ever, is less decided than that of its congeners; for
readily in moist or heated air, and its precipitated
boiling with water. All three metals manifest bo
former being shown most strikingly by arsenic and t

Vanadium was formerly regarded as a hexad ar
indeed obtained three oxides to which he assig
VO^3 [$V = 68{\cdot}5$; $O = 8$]. The highest of these, na
exhibits considerable resemblance to chromic anhy
red or orange-coloured, non-fusible, crystalline soli
by heat, and uniting with basic oxides to form very
example the native chromate and vanadate of lea
chromate or anhydro-chromate of potassium, and the
other hand, vanadium was known to form compou
compounds of the phosphorus and arsenic group, v
compound of vanadate and chloride of lead, being
morphite and mimetesite, minerals consisting res
calcium, phosphatochloride of lead and arsenatochlo
rise to the suspicion that vanadium might belong to
and this view has been completely established by th
shown that the supposed metallic vanadium of Berz
the quantities of oxygen in this and the three high
the proportion of the numbers 2, 3, 4 and 5, these o
the formulæ V^2O^2, V^2O^3, V^2O^4, V^2O^5, and the me
isolated by reduction of the chloride with hydroge
Roscoe has also shown that vanadic anhydride V^2O
classes of salts, viz. orthovanadates $3M^2O.V^2O^5$,
metavanadates $M^2O.V^2O^5$, analogous to the three
He has also obtained the three chlorides VCl^2, VC
one of them, $VOCl^3$, being analogous to phosphorous
of the di- and tetra-chlorides, which are confirme
respective compounds, show that vanadium exhibit
that the variation of atomicity or combining capac
pairs of units; in other words, they show that
perissad.

Tantalum and Niobium differ from the pent
solely pentadic, and not forming any triadic compou

Tantalum, discovered in 1802 by Ekeberg in
Finland, was formerly regarded, in accordance with
tetrad, forming the chloride $TaCl^4$ and the oxide
observations of Marignac on the isomorphism of th
and the vapour-density 12·42 of the chloride, as det
appears that the true formula of the chloride is Ta
anhydride Ta^2O^5 [Ta = 182]. There is also a lo
662–669.)

Niobium or Columbium, discovered by Hatch
was pronounced by Wollaston in 1809 to be identica
the more exact experiments of H. Rose have shown
They occur together in almost all tantalites and co
that of Kimito in Finland, are free from niobium, a
bites contain only the latter metal unmixed with
extremely difficult to separate, and it was their simul
the early analyses of the minerals containing them.
$NbCl^5$, and an oxychloride $NbOCl^3$ [atomic weight c
which are established by their analyses and vapour-
dride Nb^2O^5 unites with basic oxides forming the
are niobates of iron and manganese, (FeO; MnO)N
there are also two lower oxides NbO and NbO^2, b
established. (See vol. iv. pp. 48–58.)

Group VI. Hexad Metals.—The metals char
tellurium, molybdenum, and tungsten—are
hexatomicity, however, appears to be established b
certain of their compounds and the similar hexato
sulphur and selenium, thus:

SCl^2O^2	. .	. .	Mo
SH^2O^4	SeH^2O^4	TeH^2O^4	Mo
SO^3	. .	TeO^3	Mo

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ights S 32, Se 79·5, Te 129, and W 184, the specific heats of the elenium, tellurium, and tungsten approximate to the number 6·2; leat of the atom of molybdenum, Mo 96, has yet to be ascer- r-densities of the oxychloride and trioxide of sulphur are the halves atomic weights, and their molecules consequently accord with the standard. The corresponding compounds of molybdenum are also high a temperature to allow of the ready determination of their nd the same remark applies to the hexchloride and oxychloride of xide of tungsten is fixed in the fire, while trioxide of tellurium oxide and free oxygen, as does indeed vaporised trioxide of eat. The semi-metal tellurium is isomorphous with, and in its and behaviour very closely resembles, the semi-metal antimony, bviously occupying analogous positions in the sulphur and phos- ectively. The exact position of molybdenum in relation to the er is as yet undetermined. With an atomic weight much inferior, characters far more perfectly than tellurium, while its most ounds have just the constitution and general properties which nalogue of the sulphur elements might be expected to present.

f tungsten with molybdenum, though scarcely established beyond probably analogous to that of bismuth with antimony, tin with nce in atomic weight between the several pairs of elements being The trioxides of tellurium, molybdenum, and tungsten occur as which have many properties in common, including a marked hydro-salts with the stronger bases, and a capability of acting as tronger acids. Tungstic acid WH^2O^4, and its hydrate $WH^2O^4.H^2O$, d by Riche (Ann. Ch. Phys. [3] l. 5), but molybdic acid is not ed state, though its salts, formed on the type MoM^2O^4, are very nam, however, obtained both molybdic and tungstic acids in the erfectly soluble compounds possessed of considerable stability, cid characters, and altogether closely resembling one another l. 340). The trisulphides of molybdenum and tungsten are power- , which combine with sulphide of potassium to form beautiful red ine salts. The several elements now under consideration are not also tetratomic, and in some cases even diatomic, just as we have d elements are triatomic and even monatomic. Thus we have—

SCl^4	$SeCl^4$	$TeCl^4$	$MoCl^4$	WCl^4
SO^2	SeO^2	TeO^2	MoS^2	WS^2
SH^2	SeH^2	TeH^2	$MoCl^2$	. .
SCl^2	. .	$TeCl^2$	MoO.	. .

pentatomic, forming the compounds WCl^5 and WBr^5 (Roscoe): nadium it exhibits an exception to the general law of the variation s of units.

ties of the hydrides of oxygen, sulphur, selenium, and tellurium, of oxygen and sulphur among the dyad compounds, as well as of among the tetrad compounds, are the halves of their atomic spective molecules correspond with the normal two-volume standard. ounds above tabulated, the protoxide of molybdenum, and the ybdenum and tungsten, are not volatilisable, while the remainder, e not had their vapour-densities determined. In a classification ng, not to their maximum, but to their most characteristic atomi- ur, and by consequence selenium and tellurium, would probably be

ptad Metals.—The elements referred to at the commencement the head of non-metallic monads, namely chlorine, bromine, he property of forming, in addition to their respective mon-hydrides, entad, and even heptad compounds, examples of which last are espective quadroxy-acids, $Cl^{vii}HO^4$, $Br^{vii}HO^4$, $I^{vii}HO^4$, and $(I^{vii})^2O^7$. me sense the representative of tellurium and antimony, cannot -metal, but we are acquainted with at least one perfect or malleable e of its compounds may be regarded as heptadic, namely manga- omic weight 55, the atom of manganese has the same specific heat rine, bromine, and iodine, namely 6·2, and forms a well-defined tability, the permanganic acid $Mn^{vii}HO^4$, whose potassium-salt, rphous with perchlorate of potassium, $Cl^{vii}KO^4$. The general anese, however, will be more appropriately considered in the

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next section devoted to the iron family of metals.
hydrides, and hydrates is not without interest as ex
cities of the different groups of elements:—

Li′Cl	G″Cl²	B‴Cl³	C⁗H⁴
Na′HO	Mg″H²O²	Al‴H³O³	Si⁗H⁴O⁴

Having regard to the upper line of compounds, ca
the apex of two converging series of elements of in
regard to the lower line of compounds, it will appe
series. It is observable that the atomic weights of
closely with the arithmetical means of the atom
respectively on the same lines with them, for $\frac{8.8}{7} = 1$

Group VIII. Iron Metals.—The elements
most part capable of being arranged in two gene
combine with an odd or even number of atoms of
them as combine with two, four, or six atoms of chl
and to those which combine with one, three, five,
the designation perissad may be conveniently a
however, as already observed, unite both with odd
elements; and the same property is exhibited by
Such elements may not inappropriately receive t
Among the members of this group attention will be
the metals iron, nickel, copper, manganese, an
several series of compounds formed by these metals
compounds of zinc, in their saline constitution, wa
and general chemical properties. Accordingly, if
with the atomic weight 65, then iron, nickel, copper
be regarded as dyadic, and receive the atomic weig
the formerly received atomic weights given on the l

Fe 56	Ni 59	Cu 63·5
Fe 28	*Ni* 29·5	*Cu* 31·75

With these doubled atomic weights, the iron-metals
expressed approximately by the number 6·2, inste
expressed by the number 3·1; and several other ad
cation will be manifested further on. Adopting, t
in harmony with the specific heats of the metals, th
salts will be represented as dyad compounds by the
Some evidence also of the existence of tetrad com
Mn⁗O², iron-pyrites, Fe⁗S², and an artificial sulp
according to experiments made by the author, there
tetrachloride of manganese, MnCl⁴, corresponding
lead, PbCl⁴, just as the peroxides of the two metal
with one another. Be this as it may, the ferrat
Mn⁶K²O⁴, analogous to the sulphates SK²O⁴, furnis
of hexad compounds; and the mutual analogy of th
obvious argument in favour of adopting the atomic
alone they can all three be represented by analogo
one another of the five metals now under consid
parallelism subsisting between nickel and cobalt.
nickel serves to connect iron and copper with one
the former metal corresponds evidently with that o
ciation of copper with iron through the intervention
that thorough recognition to which, in the auth
Mag. xiii. 486), apparently because of the facility w
separated from one another. The three metals hav
88, which is likewise that of manganese, cobalt,
other metal whatever. Their specific gravities, ca
regular sequence, as do also their atomic weights.
weldable, then nickel, then copper. The three met
with evolution of hydrogen, iron most readily, t
cipitate the somewhat basylous metals, tin and cad
and alike form salts of a marked green colour, c
the pink colour of manganous and cobalt salts. T
ammoniac and ammonia, iron to a slight extent onl
Their sulphides are soluble in hydrochloric acid

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while the precipitation of sulphide of iron may be prevented by a
on, that of nickel requires a larger proportion, and that of copper a very
portion of acid. The sulphates of iron and nickel crystallise with
water, and are isomorphous with one another; but sulphate of copper
lises with five atoms of water, and is isomorphous with the corre-
ate of manganese. On the other hand, the sulphates of iron and copper
ther in all proportions, the mixed salt being heptahydrated and having
lphate of iron, or pentahydrated and having the form of sulphate
ding to the preponderance of either metal. Again, the double potassio-
three metals crystallise with six atoms of water, and are isomorphous.
owever, in comparing the five metals with one another, that manganese
are at one extremity of the series, have a tendency to form hyper-
t copper, which is at the other extremity, has a tendency to form
ile cobalt and nickel are intermediate both in position and tendencies.
some of these distinctive peroxidised compounds of manganese and iron
d, and suboxidised compounds of copper on the other, that furnish
ations of perissad forms of combination. Thus, manganese, whose
haracter is shown by its forming dyad, tetrad, and hexad compounds,
ady seen, is nevertheless indisputably perissad in the permanganates.
nates, $Mn^{vii}KO^4$, for example, resemble the corresponding perchlorates
stitution, stability, solubility, crystalline form, specific heat, &c., and,
tomic weight for manganese, are expressible by similar formulæ. The
permanganic acids are analogous, unstable, and powerfully oxidising
umas has also described a volatile perchloride of manganese, supposed
loride $Mn^{vii}Cl^7$, which is decomposed by water into hydrochloric and
cids; but H. Rose has shown that it is an oxychloride $Mn^{vi}O^2Cl^2$,
romic oxychloride $Cr^{vi}O^2Cl^2$.

e opposite member of the iron group, we find copper furnishing a whole
which, represented by the most simple formulæ with the doubled atom of
, agree closely in chemical constitution and properties, as well as in
d crystalline form, with the corresponding salts of the monad metal
ıs chloride CuCl, and silver chloride AgCl, agree in the following
ney have the same specific heat and crystalline form; are producible as
tes insoluble in water, but soluble in ammonia and in boiling hydro-
form colourless solutions. They dissolve also in solutions of the alka-
orming similar double salts, which Becquerel obtained electrolytically in
ıs belonging to the regular system. The bromides and iodides of the two
nd with one another and with the chlorides, in form, solubility, reaction
production of double salts, &c. &c. The amorphous oxides, Cu^2O
emble one another, but oxide of copper has alone been obtained in
are octahedral. The sulphides exhibit a remarkable correlation.
le, Cu^2S, is dimorphous, and while the artificial compound is isomorphous
ce, Ag^2S, in the regular system, the native form or copper-glance is iso-
silver-copper-glance, AgCuS, in the trimetric system. Miargyrite and
er are similarly constituted compounds, $AgSbS^2$ and $CuSbS^2$ respectively,
te $Pb''CuSbS^3$, and red silver Ag^3SbS^3, are similar and isomorphous.
lity of cuprous into cupric compounds constitutes, indeed, the only
rity of behaviour distinguishing them from the similar compounds of
as they continue to be cuprous compounds, the resemblance between
silver analogues is as great as that between the corresponding con.
two associated metals. But despite the analogy of cuprous to silver
stance, and of permanganic to perchloric acid, it has been proposed to
ecular formulæ of all cuprous and permanganic compounds, and conse-
ess them by formulæ dissimilar to those of their respective silver and
ues. By this means the formulæ Cu^2Cl^2 and $Mn^2H^2O^8$, for instance,
e brought into harmony with the law of even numbers, but at a very
of simplicity and analogy. Fully admitting the great and not generally
ue of Laurent and Gerhardt's law, it must yet be remembered that
hed chemists themselves pointed out its inapplicability to the perissad
the iron metals, save by admitting for each metal two different atoms
two different symbols; and it may also be asked whether the received
sing Laurent and Gerhardt's law might not be advantageously modified
dictum as the following, that "in every compound the sum of the
quivalencies is an even number."

er and manganese, though usually dyadic, are associated with monadic
adic chlorine respectively, so is iron, though usually dyadic, associated
minium. Ferric chloride, oxide, and compounds generally, present such

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an analogy to aluminic chloride, oxide, and compound
ought necessarily to be applied to the similar series o
simplicity's sake to the case of the two chlorides,
formulæ $AlCl^3$ and $FeCl^3$, on the one hand, and the
other. The more complex expression for ferric chloride
by several considerations of indisputable importance
of such paramount importance as positively to requir
Fe^2Cl^6 is in harmony with the law of even numbers
simpler formula would agree equally well with the la
above proposed. Again, the formula Fe^2Cl^6 is in
certain mixed and basic salts of ferricum investigated
Kestner (Bull. Soc. Chim. 1863, p. 344), in which
bined with the ferricum differs from the remaining fi
for example, $Fe^2(C^2H^3O^2)^3(NO^3)^2HO$, or $Fe(C^2H^3O^2)$
salts known to be formed on duplicate types is now so
tion of any extreme consequence. No one, for instance
tri-acid oxalate of potassium, $C^2H^2O^4.C^2HKO^4$, ne
formula $C^4H^4O^8$ to oxalic acid. Lastly, the formul
vapour-density of ferric chloride, as determined
volumes of vaporised ferric chloride contain tw
times 35·5 parts of chlorine, just as two volumes of
contain twice 27·5 parts of aluminium, and six times
no doubt a very important result, and one which, unle
direct or analogical, would be decisive of the quest
certain bodies of which the acertained vapour-densities
as a matter of experiment, discordant with the chemica
For instance, the quantity of phosphorus which bears
hydrogen, PH^3, the same relation that the molecule o
ammonia, has only half the bulk of these several m
white arsenic which bears to the molecule of arsenious
that the molecule of water bears to the molecule of h
bulk of these several molecules. Lastly, the quantity
to the molecule of aluminic ethide, $AlEt^3$, the relatio
sublimate bears to the molecule of mercuric ethide
several molecules. In these cases, the results flowin
free phosphorus, arsenious oxide, and aluminic chlori
to the normal volumes of other volatile compou
aluminium respectively; and bearing in mind the gr
and ferric compounds, is it not probable that the asc
may be also anomalous, and hereafter be proved to
the vapour-densities of as yet undiscovered volatil
normal volumes? Whether it be that certain bodies
corresponding to two distinct molecules, of which in
cases the extraordinary, and in other cases both, are e
it be that these bodies have each in reality but a
molecule, which in some cases has not been correctly
ment of a temperature insufficient to render the body
that the ascertained vapour-densities of a considera
harmony with their most characteristic chemical re
of instances, these anomalous results are divested o
tions of vapour-density, either of the same bodies ra
allied bodies having a more decided volatility. Eve
chloride, at the temperature at which its density was
Fe^2Cl^6, it by no means follows that under other
simpler molecular formula $FeCl^3$. Accepting the
certain other important ferric compounds will be repr
as $Fe''H^3O^3$ and $Fe'''HO^2$; the oxide as Fe''''^2O^3; th
Fe^3O^4; and iron alum as $KFe'''(SO^4)^2.12H^2O$. Th
like that of common alum, becomes a direct conseq
characteristic metal. Cobalt and manganese both fo
oxide, and manganese forms in addition an unstable
manganic alum, $KMn'''(SO^4)^2.12H^2O$. These formu
warranty upon those for the corresponding ferric com

Chromium, according to the normal atomic heat
52·5, instead of 26·25, the heretofore generally receiv
defined chlorides, viz. the dichloride $Cr''Cl^2$, trichlo
chlorochromic acid $Cr^{vi}Cl^2O^2$. This last compound i

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lensity being the half of its atomic weight, its molecule is referrible to the ume standard. The dichloride and trichloride are also volatilisable com- eir vapour-densities have not been determined. That of the trichloride, l probably present the same peculiarity as the analogous aluminic and les; and judging solely by vapour-density, the compound would conse- o be represented by the formula Cr^2Cl^6. Chromous salts correspond us salts in their general behaviour, and especially in their absorption with production of dark brown compounds. They have, however, a olour more like that of cobalt salts. Alkaline sulphydrates throw down tate of chromous sulphide, and caustic alkalis a pale coloured precipitate ydrate, soluble in sal-ammoniac and ammonia. The tendency of this to become peroxidised greatly exceeds even that of ferrous hydrate, as radual deoxidation of water with liberation of hydrogen. The double ome and potassium, $K^2Cr''(SO^4)^26H^2O$, is isomorphous with the similar c. Chromic and ferric compounds again present a general similarity of igh with some well-marked differences. Chrome-iron $Fe''(Cr''')^2O^4$ is ith magnetic oxide $Fe''(Fe''')^2O^4$; chromic oxide $(Cr''')^2O^3$, with hæmatite mic alum $KCr'''(SO^4)^2.12H^2O$, with iron alum $KFe'''(SO^4)^2.12H^2O$, &c. similar compounds of ferricum, chromic oxide is decomposed by fusion d alkalis into chromate and an inferior oxide; chromic hydrate is solutions of caustic alkalis; while chromic salts react with sulphide of roduce chromic hydrate and sulphuretted hydrogen, though this last possibly be only one of degree depending upon the difficult reducibility pounds: for it is doubtful at least whether the precipitate produced by monium in ferric salts is other than a mixture of sulphur and ferrous omic anhydride $Cr^{vi}O^3$, the most characteristic of all the compounds of well defined salts having the same general formula as the manganates, lphates XM^2O^4. Its resemblance to vanadic anhydride, a compound e pentad group, has been already noticed (p. 968).

s usually classed with the iron metals, for although possessing but little en to them, it has still less to any other group of elements. The for- m-compounds, and the atomic weight of uranium must be regarded for not finally determinable, since the analytical results cannot yet be ny considerations derived from vapour-density, isomorphism, specific chemical analogy. The proportion of uranium which unites with 35·5 ne in uranous chloride, is found to be 60 parts, and accordingly the of the metal may be fixed at 60, or 120, 180, 240, &c. The ready anous chloride is in favour of its molecule containing more than one, n more than two atoms of chlorine; while the high specific gravity of would seem to associate its atomic weight with those of such heavy sten, specific gravity 17·6, atomic weight 184; gold, specific gravity eight, 196·5; and platinum, specific gravity 21·5, atomic weight 197; rrelation of specific gravity with atomic weight is undoubtedly subject ies. Altogether, it seems most advisable to assume that the atomic um is 240, and that the formula of its subchloride is U^2Cl^6, while that oride is UCl^4, and that of uranic oxychloride $U^{vi}O^2Cl^2$. Aqueous de and uranous salts in general have a marked green colour, but rown gelatinous hydrate, soluble in carbonated alkalis. They are mposed by the earthy carbonates, with evolution of carbonic anhydride. lack precipitate with sulphide of ammonium, and oxidise readily by r. Uranic salts are of a lemon-yellow colour, and possess in a egree the property faintly shadowed forth in a few trisalts of antimony, of being derived from their respective acids by a substitution, not of netallic oxide for basic hydrogen, which metallic oxide is transferable und to another, throughout the entire series of double decompositions lts are liable. There is accordingly no hexchloride UCl^6 or hexnitrate nly an oxychloride UO^2Cl^2 and oxynitrate $UO^2(NO^3)^2$. The oxychloride stalline, readily fusible, but difficultly volatilisable mass. The nitrate emon-yellow prisms decomposible by heat, and yielding in succession a uranic oxide, uranoso-uranic oxide. Both salts are soluble in water, yellow fluorescent solutions. These are converted into uranous solu- retted hydrogen, with separation of sulphur, and are otherwise very . They give a dark brown precipitate with sulphide of ammonium; ystallisable double compounds with excess of alkaline carbonate, the having the formula $2K^2CO^3.(U^2O^2)''CO^3$; and yield precipitates of , $K^2O.2UO^3$, for instance, with caustic alkalis.

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Group IX. Platinum Metals.—The metals
nium, platinum, iridium, and osmium, thoug
of their chemical habitudes, are nevertheless separ
associated with one another, by certain very distinct
atomic heat 6·2, their several atomic weights will
Pt 197, Pd 106·5, Ru 104, and Rh 104. The specif
having the higher atomic weights are about 21, wh
the lower atomic weights are between 11½ and 12.
weight seems to be more especially correlated with
of high atomic weight, palladium with platinum, rh
with osmium; and all six metals are found associate
state. They are all infusible save at the highest te
with the oxyhydrogen blowpipe. The platinum me
iron family in the polychromatism of their salts,
cyanides, and the perisartiad seriation of their chlor

Palladium and platinum belong to the class of no
directly with oxygen, even at the highest temperatu
directly produced oxides are reducible to the reguli
and tetrachlorides are the most characteristic of t
said to form an inferior chloride PdCl, and oxide Pd
but its ordinary salts are typified, as above remarke
tetrachloride $PdCl^4$. The former is crystallisable an
is known only in solution. They both produce cryst
of potassium, ammonium, &c. Platinum forms a w
$PtCl^4$, which by a regulated heat is convertible into
water but soluble in hydrochloric acid, and also in so
apparently a double or intermediate chloride Pt^2Cl^6
chlorides of platinum form crystallisable double s
metal, &c.

Rhodium and iridium, though permanent in the a
massive state, seem to be more readily oxidisable b
than the metals last considered. At the same time t
heat alone. The trichlorides are the most characte
and are typical of their ordinary salts. Rhodium f
of which very little is known, and a soluble deliquesc
one molecule of which combines with either two or t
to form beautiful crystalline salts of a rose-red colo
Iridium, so called from the polychromatism of its s
soluble in water, but forming soluble red-coloured s
comparatively stable trichloride $IrCl^3$, whose soluti
whose double potassio-chloride has the formula
$IrCl^4$, known only in the form of its potassio-chlori
lisable salt of almost black colour, while the corresp
occurs as an indigo-blue precipitate.

Ruthenium and osmium differ from the other plat
oxidisability, ruthenium forming a trioxide RuO^3 an
to the unknown chlorides $RuCl^6$ and $RuCl^8$, and osm
with its corresponding chloride $OsCl^6$, and a stab
tetroxides are the most highly oxidised compoun
Ruthenium and osmium, moreover, are directly oxi
air, at temperatures varying with their state of agg
are not reducible by any increased temperature to
Ruthenium forms three chlorides $RuCl^2$, $RuCl^3$, an
oxides RuO, Ru^2O^3, and RuO^2, of which the trichl
ordinary ruthenium salts. The dioxide, produced b
in a current of air, though not volatile *per se* is carr
condenses as a crystalline sublimate of well-defined
all the above oxides of ruthenium produce a soluble
of potassium $K^2O.RuO^3$. Osmium forms four ch
$OsCl^6$, all of which volatilise by heat and produc
chlorides. It also forms the corresponding oxides
additional oxide OsO^4. The trioxide, though scarce
potassium-salt $K^2O.OsO^3.2H^2O$, which crystallises
to have decided acid characters. Tetroxide of osm
body. It occurs in flexible acicular colourless crys
fuses at a gentle heat and boils at 100°, with co

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pecific gravity is the half of its atomic weight. It seems to be quite properties, since it is evolved from its solution in caustic alkalis by n, while its solution in water has no action upon litmus paper.

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al relations subsisting between the atomic weights of the several for a long time past excited considerable interest among chemists, and rally led to a considerable amount of speculation.

hese atomic weights range from 1 (hydrogen) to 240 (uranium) the whether the varied chemical properties of the elements are distributed phazard, or according to some definite system, of which the relation- between their several atomic weights may possibly serve as a key. weights, as distinguished from the combining proportions, of yttrium, lanthanum and didymium, must be regarded for the present as quite of the 58 elements, however, whose atomic weights have been more or ined, 46 have atomic weights ranging from 1 to 137 in an almost sion; 10 of the other 12 have atomic weights ranging from 184, that 210, that of bismuth; while the remaining two, namely thorium and he closely approximating atomic weights 238 and 240 respectively.

*Elements, in Order of Atomic Weight.**

3	4	5	6	7	8	9	10	11	
Na 23	K 39	—	Rb 85	Ag 108	Cs 133	—	—	—	RCl
Mg 24	Ca 40	Zn 65	Sr 87·5	Cd 112	Ba 137	—	Hg 200	—	RCl^2
Al 27·5	—	—	? Y† 88	In 113	? Di 138	? Er 178	Tl 204	—	RCl^3
Si 28	Ti 50	—	Zr 89	Sn 118	? Ce 140	? La 180	Pb 207	Th 231	RCl^4
P 31	V 51	As 75	Nb 94	Sb 122	—	Ta 182	Bi 210	—	RCl^5
S 32	Cr 52	Se 79	Mo 96	Te 129	—	W 184	—	U 240	RCl^6
Cl 35·5	Mn 55	Br 80	—	I 127	—	—	—	—	RCl^7
—	Fe 56	—	Ru 104	—	—	Os 195	—	—	RCl^8
—	Co 59	—	Rh 104	—	—	Ir 197	—	—	—
—	Ni 59	—	Pd 106	—	—	Pt 198	—	—	—
—	Cu 63	—	*Ag* 108	—	—	Au 199	—	—	—

the symbols of the elements are arranged in the order of the atomic only in the case of tellurium, the symbol of which is placed imme- istead of below that of iodine; its atomic weight has perhaps been estimated. Departing from the order of numerical seriation in this it is remarkable with what facility the symbols of the elements may parallel lines and columns, corresponding with a natural classification themselves into analogous groups and series. Indeed a study of the f elements at present known would seem to indicate that they are one ed with each other by a certain community of relationship, of which the dation and parallelism in properties and atomic weights, of the alkali and earth-alkali, and of the halogen and oxygen families of only the most prominent examples.

econd line of the table as an illustration, it is observable that the first mbolised therein are distinguished from all the others by the property chloride only and that a dichloride; further that the metals in the ed columns of this line, namely magnesium 24, zinc 65 and cadmium nent in the air, volatilisable in the direct, and basylous in the inverse tomic weights, and are otherwise specially associated with one another, larly associated metals in the first three alternate or even-numbered y calcium 40, strontium 87·5 and barium 137, are quickly oxidisable in ctically non-volatile, and are basylous in the direct instead of in the their atomic weights; and similarly on the other lines of the table, e divisible into sub-groups according to their odd and even positions.

he relationship of the elements placed in the same line, the relationship in the same column is of a different kind. Taking the third and s by way of illustration, it is observable that the consecutive elements have closely consecutive atomic numbers; that the element on the a monochloride, that on the second line a dichloride, that on the third

elejeff, Ann. Ch. Pharm. viii. Supplementband, 133.
nterrogation indicate that the position in the series of the elements to which they are ul.

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a trichloride, and that on the fourth a tetrachloride seventh lines form oxides or oxychlorides correspo chloride respectively.

The preceding table shows also that about required to fill up the gaps in the different series elements may be discovered with atomic weights gr

Another idea suggested by comparisons like the probable that bodies capable of being arranged in are really elementary and mutually independent; be that the gradation of properties and atomic nu depends on their possession of different increments

METALUMINA. This name is applied by Gr soluble dihydrate of aluminium (i. 159) which Cru a solution of the acetate. Graham has shown th a solution of the acetate altered by heat, nearly and a solution of metalumina remaining on the tasteless, and neutral to test-paper.

METALYSIS. Döbereiner's name for Catal

METAMARGARIC ACID. An acid ison said by Frémy (Ann. Ch. Phys. [2] lxv. 121) to oleic acid, by treating with cold water the mixture acids produced by the action of strong sulphuric ac resulting precipitate, and treating it with alcohol acid is dissolved out. It is white, crystalline, in alcohol and ether, melts at 50°, and exhibits the of its salts were also found by Frémy to exhibit but the silver salt yielded 27—85 per cent. silver stearate of silver. Altogether, it is doubtful wh was a definite compound.

METAMERISM. See Isomerism (p. 415).

METAMECONIC ACID. Syn. with Come

METAMORPHINE. An opium-base, the hy a residue, in the preparation of opium-tincture by The *hydrochlorate* is soluble in 25 pts. of cold, and and gives no precipitate, either with ammonia or bonates. When dried at 100°, it contains 12·2 morphine, $C^{17}H^{19}NO^3.HCl.3H^2O$, contains 9·7 per The free base separated from the sulphate by and exhaustion with alcohol, crystallises in stellate dissolves in 600 pts. cold, and 70 pts. boiling wate cent. at ordinary temperatures, and in 9 pts. at the in ether. It dissolves easily in caustic potash, le carbonates. With nitric acid of specific gravity 1· aqueous solution is gradually coloured yellow by chloride. Chloride of gold first forms with it a brownish precipitate, but produces no blue color Pharm. [2] cv. 141.)

METAMORPHISM. A term applied to th rocks by physical and chemical action. (See Geol

METAMYLENE. A compound polymeric w tained in the higher portion of the distillate produc sulphuric acid. It has not been obtained pure. (

METANAPHTHALENE. See Naphthale

METANTIMONIC ACID. See Antimony

META-OCTYLENE. See Octylene.

META-OLEIC ACID. An oily acid produce oleic acid. It is insoluble in water, easily soluble (Frémy, Ann. Ch. Phys. [2] xv. 128.)

METAPECTIC ACID. See Pectic Acid.

METAPECTIN. See Pectin.

METAPHOSPHORIC ACID. See Phosph

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ATES. Silicates of the augite type, M^2SiO^3 or $M^2O.SiO^2$

NIC ACID. See STANNIC ACID, under TIN.

DL. Syn. with METACINNAMENE (see CINNAMENE, i. 982).

ARIC ACID. See TARTARIC ACID.

BENTHENE. See TURPENTINE.

STIC ACID. See TUNGSTIC ACID.

Breithaupt's name for a fibrous variety of serpentine from Schwarz-. Hardness = 2 to 2·5. Specific gravity = 2·52. Greenish-pearly lustre. Contains, according to Kühn (Ann. Ch. Pharm. lix. ent. silica, 41·00 magnesia, 2·20 ferrous oxide, and 12·95 water

. A mineral resembling metaxite, occurring in green serpentine at kåranta in Finland. Hardness, between calcspar and gypsum. 2·58 to 2·61. Colour, from greenish-black to white. Sometimes ious, sometimes radio-fibrous and spherical. Contains, according C. G. Hällsten (Jahresb. 1862, p. 749), 40·63 per cent. silica, ferric oxide, 12·88 magnesia, 16·03 lime, and 12·88 water (= 99·37).

DUST.
IRON.
MUD.
STONES.
} See the next article.

S. *Aerolites. Uranolites.* This name includes, not only those hich are known to have fallen on the earth's surface from the t likewise a great number of others, which, though their origin is n, yet agree so closely with known meteorites in mineralogical and on, as to justify the conclusion that they are also of meteoric origin. alyses which have been made of meteorites, both the older ones by oth, and Vauquelin, and those of more recent date by Berzelius monstrated in them the presence of about 18 elementary bodies, all of r in terrestrial minerals, viz. aluminium, calcium, carbon, chromium, n, magnesium, manganese, nickel, oxygen, phosphorus, potassium, itanium, tin, and perhaps also in some cases, antimony, arsenic, and lead.

livided into two classes, distinguished as Meteoric Iron, and es. Meteoric iron consists chiefly of metallic iron alloyed with oxidised compound, and has in general the characters of ordinary e stones are mixtures of several minerals, chiefly silicates (felspar, ch also play an important part in terrestrial minerals.

owever merely artificial, inasmuch as many meteorites are mixtures th masses of meteoric stone, or with one or more of the minerals ic stones. If the metallic portion predominates, the meteorite is iron, as for example the so-called Pallas meteorite, found at Kras- or that of Atacama, both of which contain larger or smaller masses in cavities in the iron. If, on the other hand, the earthy portion minates in amount, the meteorite is called a meteoric stone, although grains of meteoric iron diffused through the mass may give it an ifferent from that of meteoric stones consisting wholly of earthy e stones containing metallic iron are much more numerous than olly of earthy minerals.

1. Meteoric Iron.

oric iron is always a mixture, the constituents being sometimes evealing themselves only to chemical investigation. The chief part of f iron alloyed with nickel, and perhaps always with a small quantity dmixture of nickel is usually regarded as a proof of the meteoric masses of metallic iron found on or a little below the surface of tual fall has not been observed. The amount of iron in meteoric from about 80 to 95 per cent.; the nickel from 6 to 10 per cent.

lphide of iron is visibly disseminated through the mass, sometimes er large cylindrical grains. This sulphide is often regarded as Fe^3S^2 (p. 401), which does indeed occur in some meteorites; but

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those examined by Rammelsberg (Pogg. Ann. cx
iron, Fe^2S. Part of this sulphide is however distri
in so minute a state of division, that it can be de
phydric acid, which takes place on dissolving the ir
Moreover all specimens of meteoric iron, when d
a residue, varying in amount from a fraction to sev
is also a mixture, and appears under the microsco
crystallised compound, which chemical analysis s
phosphorus, usually mixed with carbon and silica
constituent of meteoric iron, appears to occur ther
states, viz. partly as graphite, partly in chemical c
account, the entire quantity of the carbon is never
of meteoric iron in acids being attended with the e
that is evolved in the solution of pig-iron. The sil
It is evident from these considerations that che
perfectly exact picture of the individual compounds
Many specimens of meteoric iron, when polished
exhibit on their surface peculiar crystalline con
figures.' These figures were attributed by Berzel
disseminated through the mass, which alloy, being
iron, was brought to light when the latter was rem
But certain samples of meteoric iron, viz. that of t
at Greenville in Tennessee and at Clairborne in Al
taining from 9 to 12 per cent. of that metal), do no
formation is much more probably due to the phosph
site (Shepard's *Dyslytite*), which, as already observ
residue left on dissolving the iron in acids.
The analysis of the principal mass of the iron
phosphorus, doubtless arising from partial decon
acid used to dissolve the iron.
The following are analyses of a few specimens of
melsberg's *Mineralchemie* (pp. 902-920).
1. Found at Elbogen in Bohemia, and know
Specific gravity, as determined by different observe
this meteorite in hydrochloric acid, Berzelius fou
residue is a mass having a carbonaceous aspect,
spangles.
2. Bohumilitz in Bohemia. Specific gravity =
(Rumler). Dissolves in hydrochloric acid, with e
solution contains traces of phosphorus.
3. Seeläsgen near Schwiebus. Specific gravit
(Duflos); 7·7345 (Rammelsberg). In the me
grains of a sulphide of iron, of brownish-yellow c
insoluble in hydrochloric acid, and containing, accor
75·37 per cent. ferrous sulphide, 0·71 sulphide of c
nickel-iron (= 98·64).
4. Krasnojarsk in Siberia. Discovered in 17
Pallas mass. The best known meteorite of the clas
mixed with olivin and a little sulphide of iron. Sp
ler). The residue insoluble in hydrochloric acid
substance having the metallic lustre and appearin
microscope.
5. Cosby's Creek, Cooke County, Tennessee.
7·257 (Bergemann). The residue, according to Ber
ing to 2·075 per cent., containing yellow shining m
mass.
6. Braunau in Bohemia. Fell on July 14,
(Beinert). The insoluble residue is a mixture of
greyish-white, metallic-shining, strongly magnetic l
a magnetic sulphide of iron, which dissolves in hy
of sulphur, but leaves very small quantities of charc
7. Coahuila in Mexico. A mass weighing 25
The phosphide is said to amount to 1·55 per cent.
8. Atacama in Chile. Specific gravity = 7·89.
white silicate of calcium and iron, containing phosp
9. Niakornak in Greenland. Specific gravity
off hydrogen gas containing sulphur and carbon,

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Analyses of Meteoric Iron.

alyst.	1. Berzelius.	2. Berzelius.	3. Rammelsberg.	4. Berzelius.	5. Bergemann.	6. Duflos a. Fischer.
	88·23	93·77	92·33	88·04	90·09	91·88
	8·52	3·81	6·23	10·73	6·52	5·52
	0·76	0·21	0·67	0·46	0·33	0·53
	. .	. .	. .	0·13	. .	
	. .	. .	0·05	0·07	. .	
	0·28	. .	. .	0·05	. .	0·77†
	. .	. .	0·02	.	. .	
	. .	. .	0·52	0·04	. .	
	. .	. .	. .	trace	. .	
	. .	. .	. .	. .	0·02	
	1·50	1·48	0·10	0·234	1·802	0·75
	0·39*	0·34	0·04	0·088	0·183	0·33
rus	0·32	0·32	0·01	0·112	0·068	0·16
	. .	0·04	0·01			
	. .	0·03	0·01			
um	. .	. .	. .	0·046	. .	Cr 0·04
	. .	. .	trace	. .	. .	SiO^2 0·01
	. .	. .	0·01	. .	0·175	0·01
	100·00	100·00	100·00	100·00	99·188	100·00

7. Smith.	8. Field.	9. Forchhammer.	10. Uricoechea.	11. Uricoechea.	12. Pugh.	13. Pugh.	14. Bergemann.	15. Hugo Müller.
85·54	87·80	93·39	81·20	90·40	90·43	87·89	85·42	90·91
8·55	11·88	1·56	15·09	5·02	7·62	9·05	9·73	5·65
0·61	. .	0·25	2·56	0·04	0·72	1·07	0·44	0·42
0·03	. .	0·45	. .	trace	0·03	trace	0·03	trace
. .	. .	. .						
. .	. .	. .	. .	. .	. .	0·20		
. .	. .	. .	. .	. .	. .	. .	0 19	
2·04	. .	. .	. .	. .	. .	. .	. .	trace
0·21								
. .	. .	0·67	. .	trace	0·03	. .	0·84	0·07
. .	. .	0·38						
3·02	. .	. .	. .	. .	. .	. .	. .	0·50
0·12	0·3	0·18	0·09	0·16	0·15	0·62	. .	0·23
. .	. .	. .	. .	2·99	0·56	0·34	1·05	
. .	. .	. .	. .	. .	. .	. .	0·33	
. .	. .	. .	. .	. .	. .	. .	1·48	
. .	. .	. .	. .	1·11	0·34	0·22		
. .	. .	1·69	. .	. .				
. .	. .	. .	0·95	. .	. .	. .	. .	2·72
100·12	99·98	98·57	99·89	99·72	99·88	99·39	199·51	100·50

erwards disappears, leaving nothing but carbon. This crystalline ordinary phosphide of nickel and iron, but a carbide of iron con- to 11·06 per cent. carbon. The residue insoluble in hydrochloric traces of earths reacting like yttria and zirconia.

ood Hope, near the Sunday and Bushman river. Specific gravity mler); 7·66 (Wehrle). The residue consists, according to Uri- sh-yellow and colourless granules; according to Bocking, of phosphide This meteorite is one of those which do not exhibit any Widman- en etched with acids (p. 378).

th magnesium.

† With calcium and arsenic.

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11, 12, 13. From the Valley of Toluca, n
numerous masses of meteoric are found, of vario
ferric hydrate, even to the middle of their substanc
lumps contain, in cavities on their surfaces, magne
crystallised, and apparently not resulting from rece
of iron, and laminæ of nickel-iron-phosphide.

Analysis 11 is of a lump weighing 13 lbs., wh
dissolved; 12 of a mass weighing 220 lbs., much
weighing 5½ lbs.

14. Zacatecas in Mexico, with sulphide of iro
gravity = 7·48 (Bergemann); 7·35 (Rumler
with evolution of fetid hydrogen gas.

15. Also from Zacatecas. Soft, tough, difficul
structure on the surface. The residue, insoluble in
a small quantity of a black flocculent substance re
strong hydrochloric acid with evolution of sulphydri
containing 75·02 Fe, 14·52 Ni, and 10·23 P. M
regards this meteorite as distinct from that from t
mann (14), inasmuch as the latter contains neither

2. Meteoric Sto

This name, as already observed, is applied to me
most part, of earthy minerals (silicates). The
Howard, Klaproth and others, determined me
without regard to the possible existence of differ
the later researches of Berzelius, Gustav Ros
that meteoric stones are mixtures of certain sili
&c., with or without meteoric iron. In some few
of a meteorite can be distinguished by physical
showed that the meteorite of Juvenas contains m
resembling labradorite, and determined the fo
minerals. But generally speaking, the individu
not recognisable by the sight, even on microsco
determined by chemical analysis. If the stone con
is decomposible by acids, while the other is not, t
comparatively easy and certain; but if both are att
not attacked at all, or if the stone is a mixture
analysis can only show what minerals *probably* ex

The following are examples of meteoric stones
accurately determined:

α. *Containing Meteor*

1. Chantonnay, Depart. Vendée. Fell on A
black, partly grey, with black streaks. Specific gr
silicates of this meteorite consist of 51·12 per
labradorite (= 99·16). (Rammelsberg.)

2. Seres in Macedonia. Fell in June 1818.
3·71 (Rumler). Consists of a mixture of silicat
resembling olivin, nickel-iron, and magnetic pyrit

3. Blansko in Moravia. Nov. 25, 1833.
(Rumler). From an analysis by Berzelius, Ram
at 20·13 per cent. nickel-iron, 2·97 sulphide of i
33·89 augite, and 17·30 labradorite.

4. Chateau-Renard, Depart. Loiret, in Fra
gravity = 3·56 (Dufrénoy); 3·54 (Rammelsb
frénoy, of 50 per cent. olivin, and about 10 per cent.
to be made up chiefly of augite and labradorite.

5. Utrecht (Louvenhautje near). June 2, 1843
Specific gravity, 3·57—3·65 (Baumhauer). Co
mixture of olivin, augite, oligoclase, nickel-iron (1

6. Klein-Wenden, near Nordhausen in the H
mass, intermixed with yellowish-green and black
(Rammelsberg). Consists, according to Ramm
dorite, in which are imbedded nickel-iron (about 2
pyrites (magnetic pyrites or protosulphide).

7. Montréjeau (Clarac, Ausson), Depart de

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nite ground-mass, interspersed with numerous brownish round
s sizes, and greyish-white magnetic metallic granules and laminæ.
3·30. (Filhol and Lemeyrie); 3·50 (Chancel and Moi-
ns, according to the latter, 10·04 per cent. matter attracted by the
1·56 Ni, 0·07 metallic phosphides, 0·05 adhering ferrous sulphide),
72 ferrous sulphide, 45·08 olivin, and 37·51 felspar and hornblende
850.)

β. Without Meteoric Iron.

Moravia. May. 22, 1808. Specific gravity = 3·19 (Vauquelin);
er). Consists, according to Rammelsberg, of 65·15 per cent. augite,
8 magnetic oxide of iron, and 0·54 chrome-iron (= 101·59). The
t. magnesium to 2 at. calcium and 3 at. iron.
ept. Ardêche, France. June 3, 1821. Specific gravity = 3·11
ists, according to Rammelsberg, of 62·65 per cent. augite, 34·56
tite, 0·25 titanite, 1·35 chrome-iron, 1·17 magnetic oxide of iron,
pyrites (= 100·83).
Barbezieux, Dept. de la Basse-Charente, France. June 13, 1819.
3·08 (Rumler). Resembles the preceding in properties and

ear Wiborg, in Finland. December 13, 1813. Specific gravity =
Contains, according to Berzelius, magnetic iron ore, and silicates, of
ent. consist of a silicate decomposible by nitro-muriatic acid, and
sition of olivin (containing 1 at. iron to 2 at. magnesium), with
in, and alkali-metals, and 6·45 of a silicate of aluminium, iron,
lcium, the composition of which has not been determined; also a
hrome-iron.
le, South Carolina. March 1843. A very peculiar stone, consisting
of a white mineral partly crystallised and apparently monoclinic.
3·116 (Shepard); 3·039 (Waltershausen). Melts before the
e enamel. Contains also small quantities of magnetic pyrites and
lded in the mass. An analysis of the white mineral by Walters-
per cent. silica, 1·48 alumina, 1·70 ferric oxide, 27·11 magnesia,
7 water, whence it appears to consist essentially of chladnite,

aps identical with this, obtained from a mass of iron said to be from
of Grimma, was described 30 years ago by Stromeyer.
ew Hampshire. White porous mass, which melts on the edges before
ring the flame yellow. Contains, according to B. Silliman, 84·97 per
nd 2·22 soda, an unusual composition which may be represented by
$4SiO^2 + 9Mg^2O.4SiO^2$; considered doubtful by Rammelsberg.
Cape Colony. October 13, 1838. Soft black mass with a few
nits a bituminous odour when heated, and contains a resinous or
oluble in alcohol, which easily melts and chars. When ignited in
r, even after being freed from the resinous substance, it burns and
y of carbonic anhydride equivalent to 1·6 per cent. carbon. It there-
on, to which in fact its black colour is due. It contains water, even
0°. It also yields when heated a small quantity of sublimate con-
of ammonium. It acts but slightly on the magnetic needle, and
but little magnetic iron. It contains 3·8 per cent. sulphur, but does
lphur when heated, or evolve sulphydric acid gas when treated with
hence it cannot contain either iron pyrites, magnetic pyrites, or
Wöhler considers the sulphur as belonging to a sulphide of nickel
$^2S^3$, which requires 1·3 nickel to 2·5 iron, quantities agreeing with
alysis. From an analysis by Harris, made under Wöhler's direction,
cludes that the stone contains 6·94 per cent. nickel-iron-sulphide,
stone, 84·32 olivin, 5·46 undecomposible silicates, and 1·92 carbon
atters.
Debreczin, in Hungary. April 15, 1857. Dark grey, earthy ground-
white and greenish grains, resembling olivin, also numerous black
ttle, hollow within, and consisting of a colourless crystalline mineral
al. The ground-mass exhibits nothing metallic, but yields a small
o the magnet. Its composition, according to Wöhler's analysis, is
the preceding, with addition of 3·55 per cent. magnetic pyrites.
xygen gas, it gives off carbonic anhydride, together with a little water
ublimate. Alcohol extracts from it a white carboniferous substance
n and scheererite, very fusible, partly volatile, partly decomposed by

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heat, with separation of carbon. When the pulver
by alcohol, is ignited in oxygen, it turns brown an
been well dried.

9. Alais, Dept. du Gard, France. May 15, 180
up in water to a greyish-green pulp, having a stro
covered with saline effloresences when exposed to
per cent. of the stone, consisting chiefly of alkalin
oxidation of sulphide of iron contained in the st
with water, yields by distillation 0·96 per cent. gre
6·58 water, and 88·15 fixed residue, consisting of e
magnetic iron ore, together with a silicate unde
magnesia and ferrous oxide, with small quantities

From all that is at present known respecting the
berg draws the following conclusions:—

Meteoric iron consists of an alloy of iro
amounting to 6—9 per cent., or 1 at. nickel to 10—
phosphide or *Schreibersite*, sulphide of iron, carbo
sometimes also with olivin and magnetic oxide of

Meteoric stones. (*a.*) Most of them contain
in a ground-mass, probably consisting of olivin,
this class are rich in iron and magnesium, poor in

(*b.*) A smaller number, containing no meteoric

α. Containing *olivin*. These consist of olivin p
and contain magnetic oxide of iron, sulphide of iro
Kaba, Alais).

β. Not containing *olivin*. They consist of a
small quantities of sulphide of iron, magnetic oxi
rites of Stannern, Juvenas, Jonzac). They are ric

γ. The meteorite of Bishopsville consists mainly
the composition $2MgO.3SiO^2$.

Shepard (Sill. Am. J. [2] ii. 377; vi. 402;
other minerals, some of them quite new, as existi
is by no means satisfactorily established.

Meteorites are covered over their entire surfa
with a thin black, more or less shining crust, wh
a fused slag-like appearance. It is doubtless pr
heating which the meteorite undergoes during its
mosphere. This rise of temperature, which is fu
those meteorites whose fall has been observed, an
reaching the earth, have been found in a heated
attributed, in part at least, to the friction of the
which it meets in its rapid passage.

Liquid or gelatinous masses called meteoric m
been observed to fall; but their chemical constituti
said indeed to consist of volatile substances which
gether the accounts respecting them are very vagu
kind which fell near Gotha in the year 1815, is desc
of dark grey colour by moonlight. It smelt like li
observer's hand, melted to a thick liquid which q
odour like that of burning sulphur and phosphoru

The so-called meteoric dust (*Meteorstaub*),
to fall from the air on ships at a considerable dis
of terrestrial origin. Gibbs (Pogg. Ann. lxxi.
dust which fell on a ship in the Atlantic Ocean
water and organic matter), 45·58 per cent. silic
4·22 manganic oxide, 11·77 calcic carbonate, 2·21
and 0·31 cupric oxide. Ehrenberg has detect
supposed meteoric dust, and supposes that it is tra
to another by violent storms. It may sometimes

For further details respecting the chemical co
melsberg's *Mineralchemie* (pp. 901–952).

On the physical and chemical constitution, class
following works:

Partsch.—*Die Meteoriten, oder die vom Himme
im k. k. Hof-Mineralien Cabinette zu Wien*, 1843.

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—*Report on American Meteorites* (from Silliman's Journal), New-

—*Anordnung und Eintheilung der Meteoriten* (Poggendorff's
. 155).
—*The Chemical Constitution and Chronological Arrangement of*
tion, Göttingen, 1859.
-Beschreibung und Eintheilung der Meteoriten auf Grund der Samm-
ischen Museum zu Berlin (aus den Abhandlungen der konigl.
enschaften zu Berlin, 1863), Berlin, 1864.
list of meteorites from the earliest records down to A.D. 1824, is
les de Chimie, tome XXX., and in Ure's *Dictionary of Chemistry*,
24.

yn. with MYRISTIC ALCOHOL.

LUMINIC. AlC^3H^9, or $AlMe^3$. (Buckton and Odling, Proc.
) When mercuric methide and excess of aluminium clippings con-
ibes are heated for some hours in a water-bath, the mercury com-
aluminium, thus:

$$3HgMe^2 + Al^2 = 2AlMe^3 + Hg^3.$$

ut of contact with air, the aluminic methide is obtained as a colour-
which at a little above 0° congeals into a transparent crystalline
adily at 130°. At and above 220° its vapour-density was found to
ical density calculated for the formulæ $AlMe^3$ being 2·5. But its
r expansion, increases rapidly with every decrease of temperature, so
it becomes 3·96 or 4·1; while at its boiling point 130°, it is as high as
nates to the theoretical density 5·0 calculated for the formula Al^2Me^6.
takes fire spontaneously on exposure to air, burning with a very
roducing abundant flocculi of alumina discoloured by soot. By a
to dry air, it absorbs oxygen, with production of a body apparently
dioxymethide (p. 986). It is decomposed by water with explosive
with iodine to form iodo-derivatives and iodide of methyl.
ide, AlE^3, is made by a precisely similar process, using mercuric
mercuric methide. It is a colourless liquid which does not
It boils at 194°, and its vapour-density taken at 234° was found to
al density calculated for the formula $AlEt^3$ being 3·9. The excess
over the calculated density was obviously due to some unavoidable
bstance examined. Aluminic ethide takes fire spontaneously on ex-
its other chemical properties closely resembles the methyl compound.
im. Phys. [3] lviii. 5) observed that aluminium was attacked by the
nd ethyl at 100°—130°, and that the crude ethylated product reacted
-chloride to form a very inflammable liquid which was doubtless

ote, that the vapour-volumes of aluminic ethide (AlE^3 = 2 vols.),
ethide at 220° and upwards ($AlMe^3$ = 2 vols.) are discordant with
of aluminic chloride as determined by Deville ($AlCl^3$ = 1 vol.);
-volume of the methide taken at 130° corresponds very nearly there-
uld seem that the only observed volume of the chloride, like the
ide at 130°, is anomalous, probably in consequence of its vapour not
ntly heated to acquire that perfection of elasticity under which alone
ir is regulated by the physical laws of temperature and pressure
W. O.

BORIC. See METHYL, BORIDE OF (p. 384).

MERCURIC. See MERCURY-RADICLES, ORGANIC (p. 927).

PLUMBIC. See LEAD-RADICLES, ORGANIC (p. 503).

STANNIC. See TIN-RADICLES, ORGANIC.

ACID. An acid obtained by decomposing neutral sulphate of
Liebig). It has been shown by Buckton and Hofmann (Ann.
to be identical with disulphomethylic acid, $CH^4S^2O^6$. (See SULPHU-

TIC ACID. Syn. with METHYL-GLYCOLLIC ACID. (See GLYCOL-
.)

BETHYL. Syn. with Plumbotrimethyl. (See LEAD-RADICLES,

NETHYL. See TIN-RADICLES, ORGANIC.

NE, AND METHULMIC ACID. (E. Hardy, Bull. Soc.

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Chim. de Paris, 1862, p. 29, Jahresb. 1862, p. 38
substances, resembling the ulmic compounds, prod
thylic alcohol on chloroform. The immediate pro
thulmic acid and its sodium-salt, together with
hydrogen, and chloride of sodium:

$$4CHCl^3 + 6CH^4O + Na^{11} = C^5H^7ClO^2 + C^5H^6Na$$

Chloro-form. | Methylic alcohol. | Chlorome-thulmic acid. | Chlorome-mate of s-dium.

Chloromethulmic acid is black, semifluid, h
alcohol.

By boiling with *potash*, it is resolved into met
methulmic acid, $C^5H^8O^4$:

$$2C^5H^7ClO^2 + 2KHO = 2KCl +$$

Methulmic acid is dark yellow, soluble in ethe
by *bromine* into black, semi-fluid dibromometh
treated with *sulphuric acid* at 60°, is resolved into
of hypomethulmene, $C^4H^6Br^2$, a yellow-brow

Dioxymethulmic acid, $C^5H^8O^4$, is black,
soluble in alcohol.

Chlorethulmic acid, $C^6H^9ClO^2$, and chlo
produced in like manner by treating chloroform
cohol, and from these may be obtained derivatives
in composition to the methyl-compounds above de
$C^6H^8Br^2O^2$, heated to 60° with *sulphuric acid*, is
dibromide of methulmene, $C^5H^8Br^2$, a brown
alcohol, but soluble in ether. It is converted by
nitrobromide of methulmene, $C^5H^8(NO^2)Br$
potash-lye into bromomethulmene, C^5H^7Br, a
and in alcohol, soluble in ether.

Compounds similar to the preceding are said t
with sodium in conjunction with aldehydes, aceto
form is replaced by certain other compounds, esp
must be observed, however, that the composition
above mentioned has not been established by a
must be considered doubtful, especially as none
crystalline form.

METHYL. CH^3; often denoted by the sho
$C^2H^6 = Me^2$. The first of the series of alcohol
relation to wood-spirit that ethyl (C^2H^5) bears to

Frankland and Kolbe, in 1848 (Chem. Soc.
of ethyl with potassium, first obtained a gas ha
which they regarded as methyl. Kolbe, in the fo
methyl by the electrolysis of acetic acid; and Fr
prepared it by the action of zinc on iodide of meth
he observed in the action of chlorine on the gas ob
obtained by the second and third methods, Fran
not identical but only isomeric, and that the latte
mer consisted of hydride of ethyl, $C^2H^5.H$; but th
mer (*vid. inf.*) have shown that the products obta
gases prepared by these several methods are really
ference has yet been observed between the two, i
that methyl in the free state is not only isomeric
(See HYDRIDES, p. 182.)

Preparation.—1. *By the electrolysis of Acetic a*
of acetate of potassium is subjected to the action
gaseous products are evolved, viz. carbonic anhy
odorous gas, and a gas which smells like ether; th
phuric acid (if the smallest quantity of chloride of
chloride of methyl is formed). The gaseous mix
from carbonic anhydride, contained in one ex
oxygen, 63·8 hydrogen, 32·6 methyl, 2·1 oxide of
another experiment, 66 vol. hydrogen were obtain
acetate of potassium be divided by a porous diaph
the two poles may be collected separately, nothi
negative pole, while at the positive pole there is

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with potash and with sulphuric acid, leaves nothing but methyl
l quantity of oxide of methyl. The decomposition is expressed by
ion :

$$KO^2 + H^2O = C^2H^6 + CO^2 + K^2CO^3 + H^2.$$

ng *iodide of methyl* with *zinc*, the mode of operating being exactly
eady described for the preparation of ethyl from ethylic iodide

lly identical with hydride of ethyl, we must add to these methods
for the preparation of the latter (ii. 533). Schorlemmer prepares
strong sulphuric acid on mercuric ethide (p. 925).
hyl is a colourless and odourless gas which burns with a bluish
me. It is somewhat soluble in *alcohol*, less soluble in *water* (see
OF, ii. 797). It is perfectly indifferent to the greater number of
nixed, either in the moist or dry state, with an equal volume of
hydrochloric acid and chloride of ethyl, C^2H^5Cl, together with a
nonochlorinated chloride of ethyl, $C^2H^4Cl^2$ (Schorlemmer, Proc.
). These results were obtained with methyl prepared by the elec-
cid; and exactly the same products are formed by the action of
dride of ethyl prepared by the action of sulphuric acid on mercuric
mer, Chem. Soc. J. xvii. 962). If the chlorine is used in excess, a
he monochlorinated chloride of ethyl is obtained.

TIMONIDES OF. See ANTIMONY-RADICLES, ORGANIC (i. 344).

RSENIDES OF. See ARSENIC-RADICLES, ORGANIC (i. 400).

RIDE OF. *Boric Methide. Bormethyl.* $B(CH^3)^3$. (Frankland, p. 176; Chem. Soc. Qu. J. xv. 373.)—A gaseous compound homolo- ethyl (ii. 525), produced by the action of zinc-methyl on borate of

$$(H^5O)^3 + 3Zn''(CH^3)^2 = 2B(CH^3)^3 + 3Zn''(C^2H^5O)^2.$$

thylic ate. — Zinc-methyl. — Boric methide. — Ethylate of zinc.

bout two ounces of boric ether were mixed in a small flask with
eir own bulk of an ethereal solution of zinc-methyl, of such strength
usly inflammable in a high degree. The flask, loosely corked, was
vater, and allowed to stand for a couple of hours until the reaction
was then furnished with a bent tube passing through a cork, to
nto a second flask placed in a freezing mixture of ice and salt;
gas passed into a third containing about half an ounce of strong
ia. The air in the whole of the apparatus was now displaced by
lask containing the boric ether and zinc-methyl removed from the
slow evolution of gas immediately commenced, and was kept up at
by plunging the generating flask into cold water, to which heat was
d. The gas, in passing through the freezing mixture, deposited
the ether and zinc-methyl vapour with which it was contaminated;
e solution of ammonia, the boron-compound was instantaneously
her gases, if present, passed through the ammonia unacted upon,
e atmosphere. The solution of ammonia soon became covered with
er liquid, which increased in quantity until the stream of gas ceased
he ammonia-flask was now disconnected from the rest of the appara-
r the next operation. The residue in the generating flask solidified
s on cooling.
gaseous boron-compound from its combination with ammonia, the
fitted with a funnel-tube terminating beneath the surface of the
delivery tube, the latter leading to a Liebig's potash-apparatus
ntrated sulphuric acid; finally, the opposite extremity of the latter
ected with a mercurial gas-holder. To prevent dangerous explosions,
of the spontaneously inflammable gas from its ammonia-compound,
-spaces of the apparatus were filled with nitrogen. Everything being
e sulphuric acid was gradually poured into the ammonia-flask through
contents of the flask being frequently agitated. No gas was evolved
ammonia was saturated; then, however, it was given off abundantly,
of a few drops of sulphuric acid, from time to time, through the
to keep up a convenient current. The gas was allowed to pass
depressed mercurial gas-holder until a sample of it proved, by its
ammonia, that all nitrogen had been swept from the apparatus.

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The exit-tube of the gas-holder was then closed, s
collected.

Properties.—Boric methide is at ordinary temper
gas, possessing a peculiar and intolerably pungent
brane, and provoking a copious flow of tears. It
1·9108; by calculation, 1·93137. It retains its ga
cold of 16°; but at 10°, and under a pressure
to a colourless, transparent, and very mobile liqui
water, but very soluble in *alcohol* and in *ether*.
takes fire spontaneously, burning with a bright gre
the volume of the flame be considerable. If the g
$\frac{1}{10}$ of an inch in diameter, the amount of smoke is s
inches of gas, when consumed in this way, filling t
with large comet-like flocks of carbonaceous matte
part at least, to the formation of a superficial coatin
particles of carbon and prevents their combustio
mospheric air or *oxygen*, boric methide explodes w
air, both boric methide and the vapour of boric et
spontaneous combustion. Thus, when these bodies
into the air, they burn with a lambent blue flame
perature of which is so low that a finger may be he
inconvenience. Under these circumstances partial
to the products thus formed that the peculiar p
boric methide is due. When, on the other hand, t
rapidly, the lambent blue and nearly cold flame chan
mentioned.

Boric methide is not acted upon by *nitric oxi*
chromate of potassium scarcely affects it, but the add
at once determines the reduction of the chromic aci
to bubble through water into *chlorine*, each bubble l
of light and separation of carbon. It has no te
centrated sulphuric acid has no action upon it; wh
suffers no change; but, on the other hand, it is freel
alkalis, and by *ammonia*. If a very rapid current of
of marsh-gas, be passed through a stratum of stron
inch deep, not a trace of boric methide escapes abso

Ammonia-Boric Methide. $NH^3.B(CH^3)^3$.—
with an equal volume of dry boric methide, both
evolution of a considerable amount of heat, and pro
line compound. The latter is also formed when bo
of ammonia.

It is deposited from its ethereal solution in magn
rapidly volatilise without residue when exposed to
bitter taste, and a very peculiar odour, in which bo
boric methide can be recognised. Ammonia-boric m
about 110°. In a current of air, or better, of carbo
gentle heat, and condenses in magnificent arborescen

Its vapour-density is found by experiment to be 1·
the state of vapour occupies four volumes $\left(\frac{17 +}{\right.}$
a result probably due, as in other cases, to the dec
temperatures (i. 469; ii. 816).

It scarcely absorbs a perceptible amount of *oxyg*
after several days' exposure to the gas, but tak
in contact with the air. Its vapour is also very ir
boric methide is placed under the receiver of an ai
drawn, the explosion of the mixture of air and vapou
frequently determined by the rise of temperature c
the pistons when the rarefaction has become conside

Boric methide is also absorbed by *aniline* with gr
from this compound unchanged.

Trihydride of phosphorus has no action upon bo
volumes of the two gases is spontaneously inflammab
flame, in which the characteristic green tinge attendi
is no longer perceptible.

Compounds of Boric Methide with fixed A
with potash, soda, lime, and baryta. The *potassium-*

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ution of caustic potash with boric methide, dries up in vacuo to a may also be prepared by decomposing ammonia-boric methide with id evaporating in vacuo.

c, and *calcic* compounds are also prepared by passing boric methide utions of the respective alkalis; they are soluble in water, and have n.

OMIDE OF. CH^3Br. *Methyl-hydrobromic ether. Hydrobromate* ierre, J. Pharm. [3] xiii. 156; Jahresb. 1847–48, p. 672.—Pharm. xlvi. 44.)—Prepared by mixing, at a temperature of 5° or 6°, , 200 of methylic alcohol, and 7 of phosphorus. The temperature eously, and the phosphorus melts. The mixture must be cooled, cautiously distilled. As thus obtained, it is a colourless liquid, of ghtly alliaceous odour; boils at 13° under a pressure of 0·759 met. violently on cacodyl, forming bromide of cacodyl, and bromide of um (Cahours, Jahresb. 1861, p. 554):

$$(CH^3)^2 + 2CH^3Br = As(CH^3)^2Br + As(CH^3)^4Br.$$

he composition of bromide of methyl, is evolved on gently heating f cacodyl. It has a density of 3·253 (Bunsen, *Gasometry*, p. 121), 4; a faint ethereal odour, and condenses at −17° into a thin, transquid. It burns with a yellowish flame when mixed with air, and with oxygen on the application of flame.

HLORIDE OF. CH^3Cl. *Methyl-hydrochloric ether. Hydro-ne.* (Dumas and Peligot (1835), Ann. Ch. Phys. lxi. 193).—Prea mixture of 2 pts. chloride of sodium, 1 pt. of wood-spirit, and phuric acid. Chloride of methyl then passes over as a gas, which may water; it is, however, contaminated with wood-spirit, sulphurous lride of methyl.

yl is a colourless gas, having an ethereal odour and saccharine taste. 36. It does not condense at −18°. Water dissolves 2·8 times its at 16°.

hyl burns with a white flame, green at the edges, producing water, and carbonic anhydride. Passed through a red-hot tube, it is ht deposition of charcoal, into a mixture of methylene and hydro-l = CH^2 + HCl (Dumas and Peligot). According to Perrot ci. 375), it deposits charcoal, and yields hydrochloric acid, marshonic oxide, naphthalene, and a substance which unites with bromine compound, melting at 40° and boiling at 220°. When passed over it yields formate and chloride of potassium, together with hydrogen

$$CH^3Cl + 2KHO = CHKO^2 + KCl + 2H^2.$$

phosphide of calcium at 200° or 300°, it yields a number of phos-, some of which appear to be organic bases. (P. Thenard.)

ne same composition and physical properties as the preceding was n, by the action of heat on basic perchloride of cacodyl. Kolbe p (Ann. Ch. Pharm. lxxvi. 37) also obtained a gas of the same ving a mixture of equal volumes of marsh-gas and chlorine exposed ht. Gerhardt (*Traité*, i. 566) regarded the first only of these the two latter as $CH^2Cl.H$.

Ch. Pharm. cvii. 181) finds that the gas produced from basic per-l, exhibits the same degree of absorbability in water as that ing wood-spirit with salt and sulphuric acid, the coefficient of h these gases being 5·034 at 7°; 4·172 at 14°; 3·462 at 20°; and loreover, the gas obtained by either of these methods forms a when passed into water cooled below 6°. On the contrary, the gas ction of chlorine on marsh-gas does not form a crystalline hydrate, aller coefficient of absorption in water (0·08 at 14°). Hence Baeyer gas produced by the decomposition of basic perchloride of cacodyl hloride of methyl, but that the gas resulting from the action of gas is a substitution product isomeric but not identical therewith. helot, on the other hand, the last-mentioned gas is really chloride y be converted into methylic alcohol by the action of potash.

hyl is not attacked by chlorine in diffused daylight, but when ct rays of the sun, it yields successively the three compounds—

ted Chloride of Methyl	CH^2Cl^2
Chloride of Methyl, or Chloroform . . .	$CHCl^3$
Chloride of Methyl, or Tetrachloride of Carbon .	CCl^4

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Monochlorinated Chloride of Methyl, CH^2Cl^2 =
of exciting odour, similar to that of Dutch liquid.
= 1·344 at 18°. Vapour-density 3·012. Treate
a slight precipitate of chloride of potassium, an
(For the other chlorinated compounds, see CHLOR
(i. 765 and 919).

METHYL, HYDRATE OF. CH^4O^2 =

spirit, Wood-naphtha, Pyroxylic spirit, Esprit d
This compound was first observed by Taylor in
among the products of the dry distillation of wo
amined by Dumas and Peligot in 1835 (Ann.
stitutes about 1 per cent. of the watery products
in combination with salicylic acid (as methyl s
stituent of the essential oil of winter-green (*Ga*
Berthelot (Ann. Ch. Pharm. cv. 241) it may be
(that compound when treated with chlorine yie
boiling with caustic potash is converted into meth
can be formed synthetically from inorganic ma
methylic alcohol can be obtained by synthesis.

Preparation. 1. *Of Commercial Wood-spirit.*
neous acid) obtained by the distillation of wood
the distillate and redistilled; the first tenth wh
oftener over slaked lime, whereupon a large qu
phuric acid is then added, which unites with
pitates a certain quantity of tar; and the liq
several times over quicklime.

The crude wood-spirit thus obtained has a stron
keeping. It contains considerable quantities o
liquid called lignone by Weidmann and Schw
of which has given rise to considerable discussion
Dancer (Chem. Soc. J. xvii. 222) to consist essen

2. *Of Pure Methylic alcohol.* To obtain nearly
cial wood-spirit, advantage may be taken of the
with chloride of calcium a compound which is no
100°, but gives off the methylic alcohol when dis
spirit is saturated with fused chloride of calcium,
long as anything volatile is given off; it is thus f
ethylene, &c., which do not unite with the chlo
distilled with water, and the aqueous methylic a
quicklime (Kane, Ann. Ch. Pharm. xix. 164).
vii. 311) it is advisable first to distil the wood-
potash or soda-lye, in order to decompose the me
times in very large quantity, then to dehydrate wi
saturate with chloride of calcium as above.

To obtain perfectly pure methylic alcohol, how
a methylic ether, and then separate the alcohol f
α. Oxalate of methyl is prepared by distilling 1 pt.
2 pts. oxalate of potassium; the crystals of this e
are decomposed by distillation with water, and th
drated by rectification over quicklime (Wöhl
β. Benzoate of methyl, prepared by passing hyd
benzoic acid in wood-spirit, distilling and precipit
with water, is decomposed by several hours boili
distilled, and the distillate rectified over quicklim

Methylic alcohol may also be obtained very ne
green (methyl-salicylic acid) with potash or soda-
quicklime; it retains, however, a slight odour of t

Properties.—Methylic alcohol is a colourless mo
odour, like that of common alcohol (the empyreum
from the impurities). Specific gravity = 0·8142 at
to the nature of the vessel, and bumps strongly d
flame, mixes with *water*, *alcohol*, and *ether*, dissol
the greater number of resins, and is therefore mu
mon alcohol. It is also used for burning in spiri

The following table exhibits the strength of pur
as determined by Ure (Phil. Mag. [3] xix. 51):

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nhydrous Methylic alcohol (sp. gr. 0·8136, at 15°) *in Wood-spirit.*

cent.	Sp. gr.	Per cent.	Sp. gr.	Per cent.	Sp. gr.	Per cent.
·00	0·8674	82·00	0·9008	69·44	0·9344	53·70
·11	0·8712	80·64	0·9032	68·50	0·9386	51·54
·11	0·8742	79·36	0·9060	67·57	0·9414	50·00
·34	0·8784	78·13	0·9070	66·66	0·9448	47·62
·22	0·8822	77·00	0·9116	65·00	0·9484	46·00
·90	0·8842	75·76	0·9154	63·30	0·9518	43·48
·30	0·8876	74·63	0·9184	61·73	0·9540	41·66
·72	0·8918	73·53	0·9218	60·24	0·9564	40·00
·20	0·8930	72·46	0·9242	58·82	0·9584	38·46
·75	0·8950	71·43	0·9266	57·73	0·9600	37·11
·33	0·8984	70·42	0·9296	56·18	0·9620	35·71

unites directly with some substances, forming compounds like the in which it takes the place of water of crystallisation. A solution of n wood-spirit leaves on evaporation crystals containing $BaO.2CH^4O$. is dissolved by wood-spirit with great rise of temperature, and the deposits large crystals of the compound $CaCl^2.4CH^4O$, which may ithout decomposition, but is decomposed by water, even at tempera- ielding a distillate of methylic alcohol.

–1. Vapour of methylic alcohol passed through a red-hot tube yields with other products (Berthelot, Compt. rend. l. 805).—2. Pure urns in the *air* with a flame like that of common alcohol, without tact with *platinum-black* it is oxidised to formic acid.—4. *Potash* in it readily, forming solutions which turn brown in contact with ylic alcohol mixed with *sal-ammoniac* and heated in a sealed tube hydrochlorates of methylamine, dimethylamine, and trimethylamine *Hypochlorite of calcium* (bleaching powder) converts it into chloro- solution of potash in methylic alcohol treated with *bromine* or noform or iodoform.—7. With *potassium* it gives off hydrogen nto methylate of potassium, CH^2KO; similarly with *sodium*.— *kaline hydrates*, it gives off hydrogen and yields a formate of the

$$CH^4O + KHO = CHKO^2 + H^4.$$

ures and with excess of alkali, as when wood-spirit is passed over , the formate is converted into oxalate, and ultimately into carbonate, attended with evolution of hydrogen (ii. 688).

ric acid acts upon methylic, partly in the same manner as upon lucing methyl-sulphuric acid, $CH^3.H.SO^4$, which, when heated in ss of wood-spirit, yields oxide of methyl. The action which ner temperatures differs, however, from that which takes place umstances between oil of vitriol and ethylic-alcohol in this ethylene (CH^2) appears to be produced, but neutral sulphate of passes over.

passed into anhydrous wood-spirit acts upon it with considerable of gas sometimes producing flame and detonation, and forms hydro- r with several chlorinated products. [The chloracetones sometimes ction result in all probability from acetone contained in the wood- o Cloez (Compt. rend. xlviii. 642; Jahresb. 1859, p. 434) the final n is a crystalline substance, parachloralide, C^2HCl^3O:

$$2CH^4O + Cl^8 = C^2HCl^3O + H^2O + 5HCl.$$

a similar manner, producing parabromalide, C^2HBr^3O. Riche xii. 323), by subjecting a mixture of wood-spirit and hydrochloric of the electric current, obtained a chlorinated liquid containing

ic alcohol is added by drops to brown *chloride of sulphur*, SCl^2, a vio- ce, hydrochloric acid, sulphurous anhydride, and vapour of methylic d, a small quantity of chloride of thionyl, $SOCl^2$, passes over, fter being heated to 80°, consists of chloride of sulphur, S^2Cl^2. of sulphur, SCl^2, appears indeed to act like a mixture of S^2Cl^2 and

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SCl^4, the former remaining unacted upon, while t
composition:

$$SCl^4 + CH^4O = HCl +$$
$$SCl^4 + 2CH^4O = 2HCl +$$

Chloride of thionyl also acts violently on meth
acid and neutral sulphide of methyl, together w
sulphurous acid:

$$2SOCl^2 + 4CH^4O = 3HCl + CH^3Cl$$

Protochloride of sulphur (or *chloride of sulpho*
on methylic alcohol, hydrochloric acid and meth
small quantity of methyl-mercaptan passes over,
sulphurous acid and neutral methylic sulphate, be
action is probably

$$S^2Cl^2 + CH^4O = SO$$

and the *chloride of thionyl* then acts on the meth
further quantities of methylic alcohol, as shown b

$$3SOCl^2 + 4CH^4S = 4HCl + 2CH$$

and by the last equation but two. (Carius, Ann
Ethyl-sulphurous chloride, $C^2H^5ClSO^2$ (the pro
of phosphorus on ethyl-sulphites), acts on meth
methylate of sodium), producing hydrochloric acid
ethyl-sulphurous acid:

$$CH^3.H.O + C^2H^5ClSO^2 = HCl + \left.\begin{matrix}CH^3\\C^2H^5\end{matrix}\right\}SO^3.$$

METHYL, HYDRIDE OF. Syn. with MA

METHYL, IODIDE OF. CH^3I.—Obtaine
8 pts. of iodine, and 12 or 15 pts. of wood-spiri
Soc. J. xiii. 69), 1000 grms. iodine, 500 methylic
distillate is mixed with water which separates the
rectified in the water-bath over chloride of ca
colourless liquid, slightly combustible, so that it
flame of a lamp; it then diffuses abundance o
= 2·237 at 22°; 2·1992 at 0° (Pierre). Boils
met. (Andrews); at 43·8° under 0·750 met.
= 4·883. It is not attacked by hydrochloric aci
Chlorine converts it into chloride of methyl,
with metallic *zinc* in a sealed tube, it yields iodo

$$CH^3I + Zn =$$

Heated with *arsenide*, *antimonide*, &c. of *potassi*
antimonides, &c., of methyl. Heated in a sealed
the iodides of ammonium, methyl-ammonium, di
the first and last of these iodides being produced ir
it yields magnesic methide (p. 756), the act
peratures; with *aluminium*, aluminic methide

METHYL, OXIDE OF. *Methylic ether.*
Peligot, Ann. Ch. Phys. [2] lviii. 19.)—Prod
wood-spirit and 2 pts. strong sulphuric acid, and
potash-lye. At ordinary temperatures, it is a ga
very soluble in alcohol, ether, and sulphuric acid,
37 times its volume of the gas at 18°). By cooling
snow and chloride of calcium, it is condensed to a li
Methylic ether unites directly with sulphuric a
sulphate, $(CH^3)^2O.SO^3$ or $(CH^3)^2SO^4$.

METHYL, PLUMBIDES OF. See LEAD-

METHYL, SELENIDE OF. *Selenmethyl.*
Dean, Ann. Ch. Pharm. xcvii. 5.)—Obtained by
phate of barium with selenide of potassium. It is
heavier than water, insoluble therein; of intensely d
and burning with a bluish flame. Strong nitric ac
ture; the solution is not precipitated by hydrochlo
down selenide of methyl from it. On attempting to

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lent reaction is set up, nitric oxide being evolved, and the temperature o high as to set fire to the mixture.

his reaction is methyl-selenious acid, CH^4SeO^3, which, by cau- nd cooling, may be obtained as a crystalline mass. It forms salts converted by hydrochloric acid into methyl-selenious chloride, which crystallises in transparent prisms, and is converted by hydro- dic acid into the corresponding bromine- and iodine-compounds.

ULPHIDES OF. Methyl forms three sulphides, represented by $)^2S$, $(CH^3)^2S^2$ and $(CH^3)^2S^3$, and a sulphydrate or mercaptan, CH^4S, ethyl-mercaptan.

e of Methyl. $C^2H^6S=(CH^3)^2S$. (Regnault, Ann. Ch. Phys. [2] compound is easily obtained by passing gaseous chloride of methyl protosulphide of potassium in wood-spirit contained in a tubulated s absorbed in large quantity, and if the retort be then heated and cool, sulphide of methyl distils over. It is a colourless, very ing an extremely disagreeable odour. Specific gravity, 0·845 at 21°. °. Vapour-density 2·115. It is readily attacked by *chlorine*. On s of it fall into a bottle filled with dry chlorine, a red flame is pro- e quantity of hydrochloric acid is obtained, together with a deposit if the temperature be kept low, the following substitution-products

ted methylic sulphide, $(CH^2Cl)^2S$. This is the product of the action of de of methyl, at a low temperature and under the influence of diffused yellow oil, heavier than water, and having a very offensive odour. retort, part of it distils over, but a considerable portion suffers altera- carbonaceous residue. (Riche, Ann. Ch. Phys. [3] xliii. 283.)

l methylic sulphide, $(CHCl^2)^2S$. Produced by exposing the preceding action of chlorine, taking care to cool the vessel at the beginning to from becoming too violent. It is a heavy yellow liquid, partly de- llation. (Riche.)

ed methylic sulphide, $(CCl^3)^2S$, is the product of the action of chlorine ed compound under the influence of direct sunshine. It is a limpid, quid, having a strong penetrating odour. It boils regularly and between 156° and 160°. Its observed vapour-density is 5·68; the ves 9·41 for a condensation to 2 volumes, and 4·7 for a condensation licating dissociation (i. 469); but the specimen operated upon was The compound is quite insoluble in water, but dissolves easily in It does not appear to be altered by aqueous potash.

ld resulting from the action of chlorine on dichlorinated methylic l colour and contains chloride of sulphur and tetrachloride of carbon, ith the first portions of the distillate, and are more abundant in pro- ılorinated sulphide was less completely dried. (Riche.)

f methyl unites, like sulphide of ethyl (ii. 545), with *mercuric chloride de*, forming the compounds $C^2H^6S.Hg''Cl^2$ and $2C^2H^6S.PtCl^4$, both of ine.

f Methyl. CH^3S or $C^2H^6S^2$. (Cahours, Ann. Ch. Phys. [3] xviii. . By passing gaseous chloride of methyl through an alcoholic solution otassium.—2. By distilling a mixture of sulphomethylate of calcium potassium:

$$)^2Ca''(SO^4)^2 + K^2S^2 = (CH^3)^2S^2 + Ca''SO^4 + K^2SO^4.$$

illate is rectified; and the portion which distils over between 110° by chloride of calcium, and again partially distilled.

nt colourless liquid, having great refracting power, and a density of ls between 116° and 118°. Vapour-density at 196° = 3·298. Has nd intolerable odour of onions.

paringly soluble in *water*, but nevertheless imparts its odour to that all proportions with *alcohol* and *ether*. (Cahours.)

may be set on fire by a red-hot body, and burns with a blue flame, odour of sulphurous acid. *Chlorine* acts violently upon it, producing which crystallises in amber-coloured rhombic tables, and is converted, on of the chlorine, into a yellow, and ultimately into a red liquid, ixture of C^2Cl^6S and SCl^2. *Bromine* likewise forms substitution- ately strong *nitric acid* acts strongly on the compound, producing d a peculiar acid which forms with potash long slender needles; ing colourless tables; and with lime and oxide of lead, soluble

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crystallisable salts.* *Sulphuric acid* dissolves th
tures; but decomposes it when heated. The com
over concentrated *potash-solution*.

Trisulphide of Methyl. $(CH^3)^2S^3$.—If th
preceding preparation is replaced by pentasulphide
disulphide is likewise obtained, but at the end of
lowish product is obtained having the composition
the disulphide with chlorine and with nitric acid.

METHYL, SULPHYDRATE OF. CH^4S
Pharm. xv. 239.)—Formed by distilling in the wa
a mixture of 1 pt. of a solution of sulphomethyla
of sulphydrate of calcium (both solutions having s
distillate with caustic potash, to free it from sulph

$$(CH^3)^2Ca''(SO^4)^2 + 2KHS = 2(CH^3.H$$

It is a liquid lighter than water, boiling at 21°, a
but even more offensive. It is slightly soluble in
yellow, and with *mercuric oxide* a white compound
a hot alcoholic solution in shining laminæ not fusi

METHYL, TELLURIDE OF. *Telluro-meth*
and Dean, Ann. Ch. Pharm. xciii. 233.—Heeren,
verbindungen, Göttingen, 1861.)—This compound
potassium with sulphomethylate of barium, the di
drops of oily liquid pass over with the water, and
for the preparation of tellurethyl (ii. 550).

Properties.—Telluromethyl is a pale yellow mob
does not mix with it. It boils at 82°, forming a
It has an extremely disagreeable alliaceous odour,
that even the breath is affected by it after some ti
dation. When set on fire, it burns with a bright
fumes of tellurous acid. Strong nitric acid oxidis

Telluromethyl behaves to oxygen, chlorine and
forming a basylous oxide and a series of salts, wh
solution of the oxide with acids, or by precipitatio

Acetate of Telluromethyl, $(Me^2Te)''\left\{\begin{matrix}C^2H^3O\\HO\end{matrix}\right.$

cubes, which have an unpleasant odour, crumble
exposed to the air, are insoluble in cold alcohol,
solution is neutral, gives with sulphurous acid a
with hydrochloric acid, a white precipitate of the c
precipitate. (Heeren.)

The *bromide*, $(CH^3)^2TeCl^2$ or Me^2TeCl^2, is obt
resembling bromide or chloride of lead, on adding
nitrate of telluromethyl. It forms shining colo
(Wöhler and Dean.)

The *carbonate*, $\begin{matrix}(Me^2Te)''\\(Me^2Te)''\end{matrix}\Big\}\begin{matrix}(CO^3)''\\(HO)^2\end{matrix}$, is difficult

The *chloride*, Me^2TeCl^2, is obtained, on addin
the nitrate, as a thick white precipitate resembli
Dean); as a colourless heavy oil, which solidifies
adding hydrochloric acid to a solution of the oxych

It redissolves when heated, and crystallises on c
rosive sublimate. It appears to be isomorphous
Dean). It melts at 97·5°, but appears not to
Solidifies from fusion in a mass having a highly cr
over with water, but its heated aqueous solution
not form any precipitate with platinic chloride. D

The *formate*, $(Me^2Te)''\left\{\begin{matrix}CHO^2\\HO\end{matrix}\right.$, crystallises i
forming a neutral solution in water, from which hy
of telluromethyl in the form of a colourless oil. (

* Muspratt (Chem. Soc. Qu. J. i. 53) gave to this acid the
its salts by the formula $C^2HMS^2O^3$; more recently, howeve
that it is identical with methyl-sulphurous acid, the formula c

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S^2.—When colourless hydriodic acid, or iodide of potassium, is dropt
nitrate of telluromethyl, a precipitate is formed of a bright lemon-
changing in a few seconds to vermillion-red. If the solutions are
precipitate exhibits at once a red colour and crystalline structure.
s a vermillion-coloured powder. The compound dissolves sparingly
e freely in hot water, and abundantly in hot alcohol, forming a red-
n. From both solutions, it crystallises in small shining, vermillion-
vhich are largest when they separate from the alcoholic solution.
ange-yellow powder. Under the microscope they appear orange-
ted light, but certain faces exhibit a fine blue surface-colour. The salt
rphous, like iodide of mercury; for on mixing the cooled alcoholic
t an equal volume of water, the iodide is precipitated, of a lemon-
in a few minutes a movement of the particles is observed throughout
precipitate soon assumes the character of vermillion-coloured crys-
The yellow variety cannot, however, be obtained in a permanent
holic solution yields red crystals by evaporation, and the compound
without decomposition. Even at 130°, it is converted into black
. (Wöhler and Dean.)

$Te(NO^3)^2$ (Wöhler and Dean); $Me^2Te\left\{\begin{matrix}NO^3\\HO\end{matrix}\right.$. (Heeren.)—Tel-
with moderately strong nitric acid, dissolves partially at first, with
our; but after a while, a violent reaction ensues, attended with evo-
ide, and a colourless solution of the nitrate is obtained, which by
n, yields the salt in large colourless prisms. Sometimes, however,
e acid is too strong or in too great excess, the salt is obtained on
crystals, but in the form of a transparent amorphous mass contain-
mixed or combined, and arising probably from decomposition of a
romethyl. The nitrate decomposes with explosion when heated. It
water and alcohol. The aqueous solution, mixed with hydriodic,
drochloric acid, yields a precipitate of iodide, bromide or chloride of
Vöhler and Dean.)

$(Me^2Te)^2\left\{\begin{matrix}(C^2O^4)''\\(HO)^2\end{matrix}\right.$, crystallises in monometric forms; it is neutral and
er than in alcohol; the aqueous solutions give with hydrochloric
of the chloride. (Heeren.)

luromethyl, Me^2TeO, is obtained by decomposing the chloride or
of silver. Either of these compounds is moistened with water, and
ently precipitated by baryta-water and well washed, is added in ex-
ecomposition begins immediately, and the mass becomes sponta-
The filtrate contains the oxide in solution.
methyl is indistinctly crystalline when dry; has an abominable taste,
deliquesces in the air like potash, and absorbs carbonic acid. Its
strongly alkaline to test-paper; eliminates ammonia from sal-am-
dinary temperatures, and forms a blue precipitate with sulphate of
us acid added to the solution immediately throws down tellurome-
of a stinking oily liquid; hydrochloric acid precipitates the white
ic acid the red iodide. On saturating the aqueous oxide with
slight milky turbidity is produced; and on distilling the liquid,
arates out, and a yellow oil passes over, which appears to be merely
hyl (Wöhler and Dean).—Heeren did not succeed in preparing
olid state; the strongly alkaline solution obtained by decomposing
h recently precipitated silver-oxide, quickly became turbid, and when
cuum, left nothing but tellurium.

de, $(Me^2Te)^2Cl^2O$, is formed by dissolving the chloride in ammonia.
d digesting the residue of sal-ammoniac and oxychloride in alcohol,
and separates from the solution in short colourless prisms. Hydro-
to the solution precipitates the chloride. (Wöhler and Dean.)
de, $(Me^2Te)^2Br^2O$, is obtained in a similar manner.

On dropping phosphoric acid into a solution of the oxide, a lemon-
of telluromethylic phosphate is produced, insoluble in water and in
rey when exposed to light, and melts when heated to a brown sub-
It dissolves in excess of phosphoric acid, forming a colourless liquid,
rless crystals by evaporation. From the aqueous solution of these
throws down the yellow insoluble phosphate, and hydrochloric acid
. (Heeren.)

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The *sulphate*, $(Me^2Te)^2\left\{\begin{matrix}SO^4\\(HO)^2\end{matrix}\right.$ (Heeren), is
with sulphuric acid, or by decomposing the solution
silver. It crystallises in large, very regular transpe
insoluble in alcohol.

Sulphochloride, $(Me^2Te^2)Cl^2S$? Sulphuric ac
chloride, forms a white flocculent precipitate whi
liquid at the same time acquiring an extremely repu
there passes over with the water a heavy oily liqu
and extremely offensive odour, and yielding sulphu
muriatic acid. (Wöhler and Dean.)

According to Heeren, sulphydric acid forms, in s
orange-yellow precipitate, which, when heated or st
sinks to the bottom in the form of black heavy oil
telluromethyl, leaving a black powder consisting of

METHYLACETAL. See METHYLATE OF E

METHYLACETONE. See ACETONE (i. 31).

METHYLAL. $C^3H^8O^2$.—A product of the ox
a mixture of wood-spirit, sulphuric acid, and perox
passes over, amongst other products, an ethereal li
Dumas (Ann. Ch. Pharm. xxvii. 135) gave the na
as a definite compound. Malaguti, however (Ann.
it is a mixture of methylic formate and methylal, of va
and is resolved by boiling with potash into formic a

Methylal is a limpid liquid smelling like acet
boiling at 42° under a pressure of 0·761 met.; its
in 3 volumes of water, and is separated therefrom by
ether. When gently heated with slightly diluted *ni*
nitric oxide, without carbonic anhydride or carboni
taining a considerable quantity of formic acid. It
by a mixture of *sulphuric acid and chromate of po*
Chlorine acts very slowly on it, producing formic a

$$C^3H^8O^2 + 6Cl^2 = CH^2O^2 +$$

METHYLAMINES AND METHYLA
homologous with the ethylamines, formed on the ty
the partial or total substitution of methyl for hydrog
dimethylamine, $N.H.(CH^3)^2$; trimethylam
ammonium, $N(CH^3)^4$. The methylamines, like
free state; but tetrethylammonium is known only
constitution to the ammonium salts. There are al
the hydrogen is replaced, partly by methyl, partly
amyl, phenyl, &c., *e.g.* methyl-ethyl-amylam
triethyl-ammonium, $N.CH^3.(C^2H^5)^4$.

METHYLAMINE. $CH^5N = \left.\begin{matrix}H\\H\\CH^3\end{matrix}\right\}N$. *M*
was discovered and fully examined by Wurt
223 and 323; Ann. Ch. Phys. [3] xxx. 443). It i
those which give rise to the formation of ethylam
of potash on cyanate or cyanurate of methyl (Wur
methyl-carbamide (methyl-urea) (Wurtz).—3. In
ammonia on various methylic ethers: thus iodide
with ammonia, yields hydriodate of methylamine
gether with iodide of ammonium and the iodid
ammonium (Hofmann).—4. By heating chloride
spirit in sealed tubes (Berthelot).—5. By the
and codeine (Wertheim, Ann. Ch. Pharm. lxxi
with anhydrous baryta (Cahours, ii. 903):

$$C^2H^5NO^2 + BaO = BaC$$

6. In combination with hydrochloric acid, by the
(Rochleder and Hlasiwetz, Jahresb. 1850, p. 4
434).—7. By the action of nascent hydrogen on
CH^5N (Mendius, Ann. Ch. Pharm. cxxi. 129).—

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sb. 1851, p. 476), and in small quantity among the products of the e acetate (pyrolignate) of calcium. (C. G. Williams, *ibid.* 1853,

By the action of potash on Cyanurate of Methyl.—The cyanurate ash-ley in a flask surmounted with a worm-tube, to condense the d separate the methylamine, which then passes on into a receiver quantity of pure water, which dissolves it. The decomposition of c ether by potash-ley, which is very slow, may be accelerated by her with solid potash mixed with a small quantity of water. The f methylamine in the receiver is saturated with hydrochloric acid ryness. (Wurtz.)

of Nascent Hydrogen on Hydrocyanic acid. Mendius mixes the ith hydrochloric acid and alcohol, adds granulated zinc, and when distils off about half the liquid, and again subjects the distillate, nsiderable quantity of unaltered prussic acid, to the action of the g this treatment a certain number of times, a solution is ulti- taining hydrochlorate of methylamine mixed with chloride of zinc; listilled with lime or potash, yields free methylamine, which may ter and combined with hydrochloric acid as before. Debus (Chem. ects the combination of the hydrogen with the prussic acid by lack. A stream of hydrogen is passed through a mixture of 15 grms. m, 15 grms. sulphuric acid, and 5 oz. water, contained in a retort, d successively through an empty vessel, a tube containing fused , a tube containing platinum-black and immersed in a paraffin bath , finally, through a Liebig's bulb-apparatus filled with dilute hydro- on as the mixture of prussic acid and hydrogen comes in contact with dense white clouds of hydrochlorate of methylamine become per- pparatus from the platinum to the acid. The prussic acid mixture to the boiling point, and kept at that temperature, with a current of ly passing through it, till the process is completed. The acid liquid evaporated on the water-bath, leaves a white residue almost wholly nd the alcoholic solution leaves on evaporation a colourless crystal- lorate of methylamine. Part of the methylamine produced in this the hydrocyanic acid, forming cyanide of methylammonium, and tinum in such a manner as to form a double cyanide of platinum um (p. 997), which surrounds the particles of the platinum-black, and ts further action. If its formation could be prevented, this method ord the readiest means of preparing methylamine.

methylamine, the hydrochlorate, perfectly dried, is mixed with twice ime, and the mixture introduced into a long tube closed at one end, as to half fill it, the other half being filled with fragments of From this tube a gas-delivery tube passes to the mercurial ng a gentle heat to the tube, beginning at the closed end, the gas may be collected over the mercury.

hylamine is a colourless gas, having a strong ammoniacal odour. urns reddened litmus-paper blue; fumes strongly with hydrochloric th its own volume of that gas, and half its volume of carbonic dly absorbed by water, and also by charcoal. It is distinguished aking fire when brought in contact with a lighted taper; it then ellowish flame, producing water, carbonic anhydride, and nitrogen, stion be incomplete, with cyanogen and hydrocyanic acid. Specific 5°, and 1·08 at 43°. When cooled a few degrees below 0°, it mobile liquid, which does not solidify in a mixture of solid carbonic Wurtz.)

he most soluble in water of all known gases. Water at 25° absorbs 2·5°, 1150 times its volume of the gas. The solution has the power- s, and is extremely caustic; it gives off the gas when boiled. It is *ine*, *bromine*, and *chlorine*. Iodine added to it, not in excess, forms ylamine which dissolves, and diniodomethylamine, $C(H^3I^2)N$, issolved:

$$3CH^5N + I^4 = C(H^3I^2)N + 2(CH^5N.HI).$$

ne appear to act in a similar manner.

ueous methylamine on metallic salts is, for the most part, similar to The salts of *magnesium*, *manganese*, *iron*, *bismuth*, *chromium*, re precipitated by methylamine in the same manner as by ammonia. thylamine forms a white precipitate, soluble in a large excess of

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the reagent. With *copper-salts*, a bluish-white p
and forming a deep blue solution. With *cadmium*
in excess. With *nickel*- and *cobalt-salts*, also, it fo
These last three reactions differ from those produc
scarcely clouded by methylamine, but the *nitrat*
mercurous salts, methylamine, like ammonia, form
chloride, a white, flocculent precipitate, insoluble i
pletely precipitated by methylamine: and the oxid
loïd itself or by potash, dissolves readily in ex
abandoned to spontaneous evaporation, deposits a
bon, hydrogen, nitrogen, and silver, and is probabl
but does not explode either by heat or by per
dissolved by aqueous methylamine. With *trichl*
brownish-yellow precipitate, which dissolves read
forming an orange-red solution A concentrated so
methylamine a crystalline precipitate, consisting
in the form of orange-yellow scales. The formati
even by slight dilution. (Wurtz.)

Decompositions.—1. Methylamine passed throu
with fragments of porcelain, is completely decomp
ammonia, and hydrocyanic acid:

$$2CH^5N = NH^3.CNH + CN$$

If the gaseous mixture, as it issues from the tube
collected in jars over mercury, the water acquires
contain hydrocyanate of ammonia, and the gas in
13·77 vol. hydrocyanic acid, 71·08 hydrogen, and

2. Two vol. methylamine exploded with 4½ vol.
N. Now 2 vol. CO^2 contain 2 vol. or 2 at. O, and
2½ vol. O must have been consumed in burning th
to 5 vol. Hence, since the volumes of elementar
contained in them, it follows that 1 molecule (
1 at. carbon, 5 at. hydrogen, and 1 at. nitrogen, tha
obtain complete combustion, it is necessary to mi
dry oxygen, and to add to the mixture, accordin
certain quantity of detonating gas, derived from th
dry. (Wurtz, Ann. Ch. Phys. [3] xxx. 451.)

3. *Potassium* heated in the gas decomposes it co
cyanide of potassium: $CH^5N + K = CNK +$
81·5 vol. pure hydrogen, numbers which are nearly
however, exhibits two stages. At first, while the
increases but little, and the residue probably conta
to amide of potassium; and this, at a higher tempe
cyanide of potassium, the latter decomposition bei
increase in volume which is observed. (Wurtz.)

4. With gaseous *chloride of cyanogen*, it forms
cyanmethylamide (Cahours and Cloez, Compt.

$$2CH^5N + CNCl = CH^5N.HCl$$

Methylamine-salts.—Methylamine is a strong
forming well-defined crystalline salts, and precipita
tions (p. 995). Its salts, like those of ethylamine,
methylamine with acids, or of methylammonium wit

Hydrochlorate of Methylamine. Ch
$CH^5N.HCl$ =

Nitrate of Methylamine. N
$CH^5N.HNO^3$ =

Methylamine-salts are soluble in water, and most
property affords a means of separating them from a
together. They are decomposed by heating with
thylamine.

Bromhydrate or *Hydrobromate of Meth*
the action of bromine on aqueous methylamine.
in alcohol, and crystallises from the alcoholic solut
an unctuous aspect and very deliquescent.

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$N)^2CO^3$.—This salt is prepared by distilling the fused hydro- of calcium. The product of the distillation is a very thick y of solid matter in the middle: the liquid is a highly concen- onate of methylamine; the solid is methyl-carbamic acid. On nts of the receiver, the methyl-carbamic acid partly dissolves and liquid portion, as it cools, deposits crystals of the carbonate, scent and volatilises even at ordinary temperatures. It is diffi- this salt free from methyl-carbamic acid.

e unites with its own volume of carbonic anhydride, forming cid (the so-called anhydrous carbonate of methylamine),

(See CARBAMIC ACID, i. 751.)

Hydrochlorate of Methylamine. Chloride of Methyl- l.—Gaseous methylamine unites with its own volume of hydro- g a white solid salt, which adheres like sal-ammoniac to the he salt is prepared by saturating aqueous methylamine with evaporating to dryness. The residue dissolves easily in boiling on cooling in fine, large laminæ, which, at the moment of their scent by reflected light. It is deliquescent; does not fuse till Heated in an open vessel to a very high temperature, it e vapours, which condense to a white powder on the surface of When a solution of this salt, either in water or in alcohol, is of potassium, hydrogen is evolved, and the liquid becomes ot succeed in obtaining by this reaction an amalgam of methyl- ng to the *ammoniacal amalgam* (i. 186). Neither is such a placing mercury in a cavity in a lump of hydrochlorate of me- ing it with the voltaic battery.

$CH^6NCl.AuCl^3$.—On mixing a solution of hydrochlorate of me- tion of trichloride of gold, no precipitate is formed; but on uid becomes very concentrated and then leaving it to cool, the n splendid golden-yellow needles, soluble in water, alcohol, and

$2CH^6NCl.Hg''Cl^2$.—Formed by evaporating a mixture of 1 at. ylamine and 1 at. corrosive sublimate. The solution, when lds bulky crystals of the double salt.

$2CH^6NCl.PtCl^4$.—Beautiful golden-yellow scales which are t dissolve in boiling water and crystallise on cooling. When mitting very copious fumes and leaving a residue of platinum hich burns in the air.

f methylamine with platinous chloride, see PLATINUM-BASES.

luble in water, insoluble in alcohol, uncrystallisable. When e of potassium, it yields methyl-carbamide, $N^2.H^3.CH^3.CO''$.

ylammonium and Platinum, $(CH^6N)^2PtCy^4$.—Formed in hylamine by passing a mixture of hydrogen and hydrocyanic d platinum-black (p. 995). Part of the methylamine formed yanic acid, and the cyanide of methylammonium thus formed the manner represented by the equation—

$$HCy + 2HCy + Pt = (CH^6N)^2PtCy^4 + H^2.$$

um-black with water, concentrating the solution over the water- it over oil of vitriol, the double cyanide separates in long pris- slight brown tint. They are easily soluble in water, and leave um when strongly heated in the air. (Debus.)

ydriodate, CH^6NI.—Produced, together with diniodomethyl- iodine on aqueous methylamine.

O^3.—Formed by saturating aqueous methylamine with nitric hen evaporated, yields beautiful, right rhomboïdal prisms, very osely resembling the crystals of nitrate of ammonium. They issolve very readily in water and alcohol. They are decomposed gaseous products, and drops of an oily liquid insoluble in water.

E, $C(H^2I^2)N$. This base, formed by the action of iodine on s a garnet-coloured powder which dissolves in alcohol, but appears ely. It is decomposed by heat, but does not explode like iodide decomposed by potash, with formation of iodide of potassium, a

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volatile product having a very pungent odour, an
(Wurtz, Ann. Ch. Phys. [3] xxx. 455.)

Dimethylamine, $C^2H^7N = N.H(CH^3)^2$. T
produced, as a hydriodate, together with other sim
methyl with ammonia (Hofmann, p. 994). It is
sulphite of aldehyde-ammonia (i. 108) in a sealed
(Petersen, Ann. Ch. Pharm. cii. 317):

$$C^2H^3(NH^4).SO^3 = C^2H^7N$$

Gössmann, who first noticed this decomposition
sulting base was ethylamine; but Petersen has
into iodide of ethyl, and heating the liquid in a s
ammonium is produced:

$$NH(CH^3)^2 + 2C^2H^3I = HI$$

The quantity of dimethylamine produced in this
Hofmann (Proc. Roy. Soc. xii. 380) finds that
greater facility by treating the mixture of the iod
&c., produced by the action of ammonia on iodide
manner already described for the separation of the c
An alcoholic solution of ammonia gently heated
vided with a condenser, solidifies into a crystallin
and of methyl-, dimethyl-, trimethyl-, and tetram
iodides separated from the sparingly soluble
evaporated and distilled with potash; and the ba
by passing over hydrate of potassium, are made t
ated worm-tube, in which dimethylamine and trim
the methylamine, condense, the ammonia and the
off as gas and condensed in water. The mixtur
treated with oxalate of ethyl, whereupon the meth
crystalline mass of dimethyloxamide, $N^2H^2(C^$

converted into dimethyloxamate of ethyl,

250° and 260°, while the trimethylamine remain
gently heating the mixture in a water-bath.
easily separated from the mixture by solution in
hydrate of potassium, yields a mixture of alcohol an
remaining behind. The distillate evaporated with
residue of chloride of dimethylammonium, from w
tained by distillation with potash. (Hofmann.
E. Lucius (Ann. Ch. Pharm. ciii. 105), by di
small quantity of a base which he regarded as di
grm. of a platinum-salt having the composition 2
Dimethylamine is a highly alkaline liquid havi
soluble in water, and boiling between 8° and 9°
platinum-salt, $2C^2H^8NCl.PtCl^4$, both crystallise w
shooting through the liquid from one side of the

Trimethylamine, $C^3H^9N = (CH^3)^3N$. Disc
J. iv. 304). Produced, together with other methy
acid, by the action of ammonia on iodide of meth
oxalic ether and subsequent distillation, as de
occurs ready formed in many organic substance
position. Hofmann (Chem. Soc. Qu. J. v. 288)
ing to Dessaignes, it occurs in human urine (
blood of the calf, twelve hours after it has been t
perfectly fresh blood (J. Pharm. [3] xxxii. 43; Ja
Cratægus oxyacantha (Wicke, *ibid.* 1854, 478; I
gyna, *Pyrus Aucuparia*, and *Pyrus communis* (Wi
foot, *Chenopodium vulvaria* (Dessaignes, *ibid.*
in craw-fish (Wittstein), and in ergot of ry
Winckler, *ibid.* 553; Rithausen, Rép. chim.
also in very small quantity in guano (Hesse, *ib*
(A. Müller, *ibid.*), and in putrefying wheat-dou
It is also produced by heating narcotine with pot
theim), or with water to 250°—260° (Reynos
the decomposition of codeine by potash-lime. (A

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ine obtained from several of these sources was formerly mistaken
$H^7.H^2.N$, with which it is isomeric.

is an oily alkaline liquid having a strong odour of stale fish. It
ann), which is but little above the boiling point of dimethylamine.
ssion of electric sparks from an induction-coil is passed through the
decomposed, yielding a tarry deposit; but even a long continuance
not suffice to set the whole of the nitrogen free. (Hofmann
. Pharm. cxiii. 129.)

cids, forming crystallisable salts. The *sulphate* mixed with *sulphate*
s large crystals of trimethylamine-alum, probably having the
$\left.\begin{matrix}N\\H\end{matrix}\right\}(SO^4)^2.12H^2O$, analogous to that of ammonia-alum; they melt at
heir water of crystallisation with intumescence at 120°. (Recken-
Pharm. lxxxiii. 343.)

unites directly with iodide of methyl, forming iodide of tetramethyl-
^4NI, and with dibromide of ethylene, yielding the compound
$^2(C^2H^4Br)NBr$. (Hofmann, see p. 1000.)

mmonium, $C^4H^{12}N = (CH^3)^4N$. (Hofmann, Phil. Trans. 1850,
Qu. J. iv. 321.) The iodide of this base is produced: 1. By the
methyl on trimethylamine, the two liquids immediately uniting into
$(CH^3)^3N + CH^3I = (CH^3)^4NI$.—2. By the action of ammonia on
Of the five iodides, H^4NI, $(H^3Me)NI$, $(H^2Me^2)NI$, $(HMe^3)NI$, and
y this reaction, the first and last are the most abundant; and when an
f ammonia is used, and the iodide of methyl is in excess, the action
w hours, the hot solution, as it cools, depositing crystals of iodide of
ium, which may be purified by washing with cold water and recrys-
t water.

etramethylammonium, $\left.\begin{matrix}(CH^3)^4N\\H\end{matrix}\right\}O$, is obtained by digesting
he aqueous solution of the iodide. On filtering to separate iodide of
lkaline solution is obtained, which, when evaporated in vacuo over
ds a white crystalline mass, resembling hydrate of potassium, and
d carbonic acid with avidity. When heated, it intumesces strongly,
olatilised, yielding a strongly alkaline distillate. According to the
ucts obtained with other bodies of similar decomposition—hydrate
ium, for example (ii. 561), it might be expected to yield trimethyl-
ene, CH^2; but it appears to be decomposed in a different manner,
rmanent gas is given off.

acids, it yields crystallisable salts. The *sulphate, oxalate, nitrate,*
have been prepared. The *nitrate* crystallises in long shining
platinate, $2(CH^3)^4NCl.PtCl^4$, in well-defined octahedrons of a deep
ur, partially decomposed by boiling with water, like the platinum-
r ammonium-bases. (Hofmann.)

'etramethylammonium.—Tetramethylammonium unites with
oportions. **α.** The *mono-iodide,* $(CH^3)^4NI$, prepared as above, crys-
t needles of dazzling whiteness; sparingly soluble in cold, more
vater. The solution is neutral and very bitter. The crystals are
alcohol, quite insoluble in ether, sparingly soluble in an alkaline
n.)

solution of iodine added to a hot solution of the mono-iodide of
ium, forms an abundant crop of shining crystals, consisting of the
$^4NI^5$. This compound is decomposed by boiling with water, yielding
d probably iodides containing larger proportions of iodine.—**γ.** On
boiling solution of the penta-iodide in dilute alcohol, a melted mass
ttom of the liquid, which on cooling solidifies to a crystalline mass
ca-iodide, $(CH^3)^4NI^{10}$.—**δ.** A solution of the mono-iodide mixed with
n of iodine containing as much iodine as is required to form the tri-
rst crystals of the penta-iodide, afterwards a mixture of the tri- and
h may be separated mechanically and purified by recrystallisation.
$^3)^4NI^3$, forms rhombic crystals having a deep violet colour and strong
luble in alcohol than the penta-iodide. (Weltzien, Ann. Ch. Pharm.

–**α.** The salt, $(CH^3)^4NI.Hg''I^2$, is obtained in small light yellow
soluble in alcohol: 1. by adding mercuric iodide to an excess of iodide
onium in hot alcoholic solution; 2. by the action of metallic mercury
tetramethylammonium, or on the following salt.

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β. $2(CH^3)^4NI.3Hg''I^2$.—This co
by adding a hot alcoholic solutio
mercuric iodide, or by the action
ammonium. (H. Risse, Ann. C

Chloriodides.—A *tetrachlori*
of ammonium, NH^4ICl^4, is obtain
silver; iodide of silver is then im
less strongly alkaline solution is
ammonium:

$$3(CH^3)^4NI^3 + 4Ag^2O + H^2$$

and on gently heating the filtered
it with iodic acid), chlorine is ev
is deposited, as a very loosely co
iodine:

$$(CH^3)^4NIO^3 + 6$$
Iodate.

The *trichloriodide*, $(CH^3)^4NIC$
mixing chloride of tetramethyl
chlorine into a solution of the n
formed, and afterwards a colour
tion.

The *dichloriodide*, $(CH^3)^4NIC$
chloriodide in shining yellow in
(Weltzien, *loc. cit.*)

Methyl-base

α. **Methyl-triethyl-ammo**
base, obtained by the action of m
tetrethylammonium (ii. 562); it i
solution which is decomposed by
tion.

The iodide decomposed by moi
to a crystalline mass resembling h
salts with sulphuric, hydrochlor
beautiful crystalline precipitate c
Qu. J. iv. 313.)

The *tri-iodide*, MeE^3NI^3, obtai
ding compound of trimethyl-eth
laminæ, dark reddish-yellow by t
Ch. Pharm. cviii. 1.)

β. **Dimethyl-diethyl-amm**
passing the vapour of diethylam
liquid to 100° in a sealed tube, fo
in alcohol. The *chloroplatinate*,
moderately soluble in water, spa
Pharm. xci. 122.)

γ. **Trimethyl-ethyl-ammo**
base is obtained by the direct uni

On adding 2 at. iodine to a v
and leaving the solution to cool
bic prisms, which are instantly re
penta-iodide: in alcoholic soluti
and form the tri-iodide. The c
splinters, brownish-yellow, and
bluish-violet; they melt at 64° w
cviii. 1.)

The *penta-iodide*, Me^3ENI^5, obt
solution with excess of iodine, or
with water, crystallises in quadra
(the latter faces very subordinate)
with metallic lustre, yellowish in
thicker layers; surface colour, m
air; they melt at 68°. (R. Müll

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promethyl-ammonium. $C^5H^{13}BrN = (CH^3)^3(C^2H^4Br)N$.*—The se, $C^5H^{13}NBr^2 = [(CH^3)^3(C^2H^4Br)N]Br$, is produced by the action olic trimethylamine on bromide of ethylene, best in sealed tubes at + $C^2H^4Br^2 = C^5H^{13}NBr^2$. It is very soluble in boiling alcohol, es in white needles, less soluble in cold alcohol, insoluble in ether. ded to the solution of this salt, throws down only half the bromine; ed from excess of silver by hydrochloric acid, yields with platinic oluble octahedral crystals of the *chloroplatinate*, $2C^5H^{13}BrNCl.PtCl^4$. *gold-salt*, $C^5H^{13}BrNCl.AuCl^3$, crystallises in golden-yellow needles. t. rend. xlvii. 558.)

inyl-ammonium. $C^5H^{12}N = (CH^3)^3(C^2H^3)N$.—The bromide, with oxide of silver gives up the whole of its bromine and yields a quid containing hydrate of trimethyl-vinyl-ammonium, $C^5H^{13}NO$ =

when neutralised with hydrochloric acid and strongly concentrated,

chloride octahedral crystals of the *platinum-salt*, $2C^5H^{12}NCl.PtCl^4$, ride the *gold-salt*, $C^5H^{12}NCl.AuCl^3$.

this base is also formed, together with the preceding, by the action on bromide of ethylene, part of the latter splitting up into hydro- bromide of vinyl: $C^2H^3Br^2 = HBr + C^2H^3Br$. (Hofmann, *loc.*

amyl-ammonium. $(CH^3)^3(C^5H^{11})N$.—The only known salt of this *ide*, which is obtained by heating a mixture of tri-methylamine and ome time to 160°, and treating the product with tincture of iodine. ark brown flattened rhombic prisms, exhibiting the combination: predominant), $\infty\bar{P}\infty$. $\bar{P}\infty$. $\frac{1}{2}\bar{P}\infty$. Angle $\infty\bar{P} : \bar{P}\ \infty = 104°\,28'$; rincipal axis = 112° 4'. The crystals exhibit trichroïsm; if they and viewed so that the light may be transmitted at right angles to y ray is dark brown or nearly black, the extraordinary ray light d tint being between the two. They melt at 80°, dissolve easily in rly insoluble in water. (R. Müller, *loc. cit.*)

e peroxides of the other bases above mentioned form with mercury, us to those already described as produced by the action of mercury f tetramethylammonium. (Müller.)

yl-amylamine. $C^6H^{15}N = (CH^3)(C^2H^5)(C^5H^{11})N$.—This base is y distillation of hydrate of methylodiethyl-amyl-ammonium, water eing given off at the same time:

$C^5H^{11})N.H.O = (CH^3)(C^2H^5)(C^5H^{11})N + H^2O + C^2H^4$.

oil, having a fragrant taste and smell, sparingly soluble in water. potash and rectification, it boils constantly at 135°. It dissolves he *platinum-salt*, $2C^6H^{20}NCl.PtCl^4$, which is very soluble in water, ixing its component salts in strong solution, or on evaporating the -yellow oily globules which gradually solidify in splendid needles. . Soc. Qu. J. iv. 317.)

thyl-amyl-ammonium. $C^{10}H^{24}N = (CH^3)(C^2H^5)^2(C^5H^{11})N$.— lide by gradually adding methylic iodide to diethylamylamine con- d retort provided with a condenser, the mixture solidifying on cooling rystalline mass. This salt is very soluble in water, forming a very n which it is precipitated by potash in oily globules which solidify igestion with oxide of silver, it is converted into the hydrate, ie form of a strongly alkaline solution which when evaporated to ed is resolved into water, ethylene-gas, and methyl-ethyl-amylamine. ate, chloride, and chloroplatinate are crystalline. (Hofmann, v. 316.)

IYL ANILINE. See PHENYLAMINES.

IYLIC ETHER. *Oxide of Methyl and Amyl*, $CH^3.C^5H^{11}.O$. See

ILINE. See PHENYLAMINES.

RSINES. See ARSENIC-RADICLES, ORGANIC (i. 400).

E OF AMYL. Syn. with METHYL-AMYLIC ETHER.

E OF ETHYL. See ETHYLATE OF METHYL, under ETHYL, OXIDE

he constitution of this and similar bases, see AMMONIUM-BASES (i. 196).

METHYLATE OF ETHYLENE. C

Ch. Pharm. cviii. 84), by distilling a mixture o
phuric acid and peroxide of manganese, obtain
ethylate of ethylene, $\left.\begin{matrix}(C^2H^4)''\\ CH^3\\ C^2H^5\end{matrix}\right\}O^2$. A compound
has recently been obtained by Dancer (Ch
spirit, and called by him dimethyl-acetal;
this or Wurtz's compound is really a derivati
prepared his compound as follows:—Crude w
tilled upwards for some time with a concentrat
the methylic acetate present; the distillate w
calcium, as long as that compound continued to
with a concentrated solution of acid sulphite
afterwards distilled upwards, with caustic pota
of the remaining methylic acetate, the methyl
of this ether being removed by chloride of ca
purified by a few distillations on sodium. The
the composition of dimethylate of ethylene (53·
boiled at 63°—64°; had a specific gravity of
4° C.) and vapour-density, by experiment 3·16
The liquid called *lignone* by Weidmann an
probably a mixture of this compound with so
wood-spirit.

METHYLATE OF POTASSIUM, SODIUM, CH^3NaO.—Compounds similar in
of the same metals (ii. 542, 543); they are ob
sodium on methylic alcohol.

METHYL-BENZOLIC or **BENZYL**
ETHERS (i. 577).

METHYL-BROMOSALICYLIC ACI

METHYL-BRUCINE. $C^{24}H^{28}N^2O^4$ =
Pogg. Ann. cviii. 503; Jahresb. 1859, p. 398.)
brucine with iodide of methyl. The *hydrio*
shining laminæ containing $C^{24}H^{28}N^2O^4.HI.8H^2$
with iodide of methyl. By decomposing this s
with baryta-water) a solution of methyl-bruc
first, but soon decomposes, turning violet, and
carbonic anhydride, and leaving a solution con
brucine. The *hydrobromate*, $C^{24}H^{28}N^2O^4.HBr.\frac{5}{2}$
of the hydrochlorate with bromide of potass
soluble in water and alcohol, and crystallising
which give off their water at 130°. The *hydroc*
by neutralising the base with the acid, forms s
water and in alcohol. The *platinum-salt*, 2(
cipitate insoluble in ether, easily soluble in al
needles from the latter. The *gold-salt*, $C^{24}H$
precipitate, sparingly soluble in cold water. *M*
the hydrochlorate, forms a white curdy precipitat
$H^2SO^4.8H^2O$, obtained by decomposing the hy
a radio-crystalline mass, easily soluble in wat
$C^{24}H^{28}N^2O^4.H^2SO^4.2H^2O$, obtained by treating
acid, forms indistinct crystals somewhat less sol
Methyl-brucine does not appear to be poisono
a rabbit did not produce any poisonous effects.

METHYL-BUTYRAL. $C^4H^7O.CH^3$.—A
butyral $C^4H^7O.H$ (i. 689), ethyl-butyral $C^4H^7O.$
distillation of butyrate of calcium. It boils at
0·827 at 0°, and vapour-density = 3·13.—*Et*
specific gravity = 0·833 at 0°, and vapour-
Pharm. cviii. 122; Jahresb. 1858, p. 295.)

METHYL-CAMPHORIC ACID. See

METHYL-CAMPHRENE, $C^9H^{13}(CH^3)C$
sodium and iodide of methyl on camphrene (i

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enzene is treated with sodium in an atmosphere of hydrogen, till the naltered even on heating, and the solution is then cohobated with e iodide. On adding water to the resulting liquid, a brown oil is ch, after repeated rectification, yields methyl-camphrene as a colourless oiling between 225° and 230°. (H. Schwanert, Ann. Ch. Pharm.

an oily body produced by heating common camphor with sulphuric who discovered it, assigned to it the formula $C^9H^{12}O$; but according as the composition $C^9H^{14}O$, isomeric with phorone (*q. v.*).

APRINOL. $\left.\begin{matrix} C^{10}H^{19}O \\ CH^3 \end{matrix}\right\}$.—This, according to Harbordt (Ann. Ch. 3), is the rational constitution of the essential constituent of oil of C. G. Williams as euodic aldehyde, $C^{11}H^{21}O.H$. (See Rue, Oil of.)

APROYL. See Methyl-hexyl.

ARBAMIC ACID. See Carbamic Acid (i. 751); also Methyl-

ARBAMIDES. See Carbamide (i. 754).

ter experiments by Wurtz (Rép. Chim. pure, 1862, p. 199), dime-

e, $\left.\begin{matrix} (CH^3)^2 \\ (CO)'' \\ H^2 \end{matrix}\right\}N^2$, prepared by the action of methylamine on cyanate of

102·5° and boils between 268° and 270°; the (identical) compound ng cyanate of methyl with water, melts at 99·5°, and boils between

l-carbamide, $\left.\begin{matrix} CH^3.C^2H^5 \\ (CO)'' \\ H^2 \end{matrix}\right\}N^2$, melts at 52° or 53°, and boils be-

38°.

ARBONATES. See Carbonic Ethers (i. 801).

HLORACETOL. $C^3H^6Cl^2$.—A compound isomeric with chloride ced by the action of pentachloride of phosphorus on acetone (i. 27).

ITRIC ACIDS. See Citric Ethers (i. 1001).

HLOROSALICYLIC ACID. See Salicylic Ethers.

ONINE. See Conine (ii. 6).

YANAMIDE. $C^2H^4N^2 = (H.CH^3.Cy)N$.—Produced, together with nethylamine, by the action of gaseous chloride of cyanogen on methyl- l Cannizzaro, Ann. Ch. Pharm. lxxviii. 228):

$$\left.\begin{matrix} CH^3 \\ H^2 \end{matrix}\right\}N\Big] + CNCl = \left.\begin{matrix} CH^3 \\ H^2 \end{matrix}\right\}NCl + \left.\begin{matrix} CN \\ CH^3 \\ H \end{matrix}\right\}N.$$

YANANILINE. See Phenylamines.

ISULPHOPHOSPHORIC ACID. See Phosphoric Ethers.

ITHIONIC ACID. CH^4SO^2. (J. T. Hobson, Chem. Soc. Qu. acid produced by the action of sulphurous anhydride on zinc- gas passed into an ethereal solution of zinc-methyl, kept cool to ion, is rapidly and completely absorbed, and in a little while, a substance is formed, which is the zinc-salt of methyldithionic acid, is salt may be freed from ether and the last traces of sulphurous acid vacuo. It may be converted into a barium-salt by treating it with baryta, and from this the acid may be prepared by precipitating the sulphuric acid.

e acid is a liquid having a feebly acid taste and reddening blue litmus. a short time, with deposition of sulphur, even in a very dilute

ionates cannot be conveniently prepared by digesting the free acid bonates, on account of the facility with which the acid decomposes; obtained by decomposing the zinc-salt with the corresponding bases, lt with the sulphates. Their general formula is CH^3MSO^2 for monatomic metals, and $C^2H^6M''S^2O^4$ for those containing diatomic

ionates are all very soluble in water, but insoluble in alcohol and ether. *t*, $C^2H^6BaS^2O^4$, is prepared by treating the solution of the zinc-

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salt with excess of caustic baryta, filtering to
the excess of baryta by a stream of carbonic
the heat of the water-bath. It is a colourless
precipitated from its strong aqueous solution by
powder. A concentrated aqueous solution left t
in cubes arranged in octahedral masses. It sust
sition.

The *calcium-salt*, $C^2H^5Ca''S^2O^4$, prepared in
uncrystallisable mass when its concentrated solu
The *copper-salt* is obtained as a grass-green solu
tion, with deposition of sulphur. The *magnesiu*
decomposing the barium-salt with sulphate of ma
forms minute colourless crystals. The *nickel-sa*
as a grass-green solution which dries up in a va
dirty buff-coloured amorphous mass. The *silve*
nate of silver in the free acid, but the solution d
to light or heated to 100°. The *zinc-salt*, C^2H^5
separates by evaporation from a very concentrat
soluble at 100°, but blackening and decomposin
what higher temperature.

Methyldithionate of Ethyl.—A mixture of t
potassium distilled at a high temperature, yiel
quantities of sulphurous anhydride. The pro
chloride of calcium, and redistilled in a vacuu
slightly heavier than water and having a peculi
high temperature required to prepare it.

Ethyltrithionic acid, $C^4H^{12}S^3O^6$, is prep
dithionic acid, the zinc-salt being obtained by
on zinc-ethyl. Its salts, which have the g
diatomic metals $C^4H^{10}M''S^3O^6$, are for the most
tallisable than the methyl-dithionates. The *bari*
$C^4H^{10}Ba''S^3O^6.H^2O$, gives off its water at 100°, a

position. The *copper-salt*, $C^4H^{10}C\ddot{u}S^3O^6$ (at 100°
solution in greenish-blue deliquescent needles.
in vacuo, contains $C^4H^{10}Ag^2S^3O^6$. It is white,
highly deliquescent. It is not decomposed by
pletely at a somewhat higher temperature. Th
tained by dissolving carbonate of sodium in
alcoholic solution by evaporation in a vacuum i

Zinc-salts.—The salt obtained by the action o
is a basic salt containing $Zn''O.2C^4H^{10}Zn''S^3O^6.3$
from the action of water on the undecomposed
first from alcohol, then from water, the normal zi
in minute, colourless, needle-shaped crystals ha
bitter taste. It retains its water of crystallisati
either hot or cold, also in ether; is nearly insolu
boiling alcohol.

Ethyl-trithionate of ethyl, $C^4H^{10}(C^2H^5)^2S^3O^6$,
barium-salt with ethyl-sulphate of potassium i
heavier than water, having an offensive odour, i
proportions with alcohol. (Hobson, Chem. So

METHYLENE. CH^2.—This compound, t
C^nH^{2n}, ethylene being the second, is not kno
Dumas and Peligot in 1835 (Ann. Ch. Phys.
through a porcelain tube kept at a cherry-red
garded as methylene. After being agitated w
chloric acid gas and undecomposed chloride of
chloric acid when burnt, it appeared as a col
vegetable colours. It burnt with a yellow flame
of oxygen, consumed 3 vol. oxygen, and produ
supposing two volumes of the gas to contain CH
quantity of hydrogen would consume 1 vol. O, a
2 vol. CO^2 with the 1 at. C in the 2 vol. of the
been quite pure, as charcoal was deposited in th
obtained no evidence of the formation of methy
chloride by heat. (See p. 987.)

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ıbts the existence of methylene, inasmuch as it is not obtained by
her, or wood-spirit, with excess of sulphuric acid. Again, Hofmann
: produced by the decomposition of hydrate of tetramethylammonium
ıe hydrate of tetrethylammonium, when treated in like manner, yields
ylene.
diatomic radicle forming ethers analogous to those of ethylene. The
chloride, iodide, oxide, sulphide, and sulpho-carbonate, have been ob-
ies is at present much less complete than that of the ethylenic ethers.

E, ACETATE OF. $C^5H^8O^4 = \left.\begin{matrix}(CH^2)'' \\ (C^2H^3O)^2\end{matrix}\right\}O^2$. (Butlerow, cxi. 242.)—This compound is produced by the action of iodide of ate of silver:

$$CH^2I^2 + 2C^2H^3AgO^2 = 2AgI + CH^2(C^2H^3O)^2O^4.$$

xture of the two substances in equivalent quantities, with the addi-
ole acetic acid, is heated to 100° for some hours; the resulting mass
il-bath; the distillate is rectified, the portion which distils above 150°
art; this portion is saturated with lime; and the acetate of calcium
water. Acetate of methylene then separates as an oil, which is
of calcium, and freed from the last traces of iodide of methylene and
tillation over dry acetate of silver and a small quantity of quick-

uid heavier than water, and having an aromatic taste with pungent
solves in water to a certain extent without decomposition; but when
d tube with a quantity of water not sufficient to dissolve it at ordi-
, and heated to 100° for twenty hours, it is dissolved and completely
ing acetic acid and a solid volatile substance which dissolves readily
ins as a white residue when the solution is evaporated in vacuo.
ene boiled with aqueous alkalis (potash or baryta-water) or heated
ed tubes, is decomposed, yielding an alkaline acetate, and perhaps
ity of formate. Neither in this decomposition nor in that by water
methylene (methyl-glycol) formed.—When acetate of methylene is
and oxide of lead in a sealed glass tube, acetate of lead is formed,
le of methylene:

$$\left.\begin{matrix}(CH^2)'' \\ (C^2H^3O)^2\end{matrix}\right\}O^2\Big] + 2Pb''O = 2C^4H^6Pb''O^4 + C^2H^4O^2.$$

osed by ammonia, but neither in this case is any methylene-glycol
cts seem to show that methylene-glycol has no existence. (But-

E, BROMIDE OF. CH^2Br^2.—Produced by the action of bromine utlerow.)

E, CHLORIDE OF. CH^2Cl^2.—Produced by the action of chlorine ylene (Butlerow, Ann. Ch. Pharm. cvii. 110; cxi. 242). When assed into iodide of methylene covered with water in a retort, and y heated, a very volatile liquid passes over into the receiver, and the crystalline form. The oily liquid, which is chloride of methy-
heating it with chlorine and a few drops of potash-lye, drying over n, and rectifying.
s liquid, heavier than water, but lighter than the iodide. It has a very much like that of chloroform. Does not solidify in a mixture Boils at about 40°.
e known boiling points of the chlorides of tetrylene, tritylene, and chloride of methylene should be 65° instead of 40°. Now according erence of boiling point between chloride of ethylene and the isomeric hylidene (ii. 599) is 25°. If then this same difference between the boil-ride of methylene and chloride of methylidene, is also 25°, the latter , as the compound now under consideration actually does. Hence not improbable that this compound is really *chloride of methylidene*, that the iodide of methylene above described is also really an iodide ut till this point is satisfactorily ascertained, it is best to designate ethylene-compounds.
hylene. or its isomer, monochlorinated methylic chloride, $CH^2Cl.Cl$,

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is produced, together with chloroform ($CHCl^2.Cl$), chlorine together in sunshine, and condensing th (Regnault, Ann. Ch. Phys. [2] lxx. 377). The ever, a much lower boiling point, viz. 30·5° (Re phosphine, forming a crystalline mass of chloride o $CH^2Cl^2 + (C^2H^5)^3P = (CH^2Cl)(C^2H^5)^3P.Cl$. (H

Chloride of Dinitromethylene. $C(NO^2)^2C$ —This compound, which is closely related to chl commonly known by the name of *Marignac's oil*, i products of the action of chlorine on naphthalene separates after a while from the acid liquid in the It is a colourless, transparent liquid, having a pungent odour like that of chloride of cyanogen, a eyes. It is neutral to vegetable colours. Water cient to impart the odour. It is very soluble i soluble in hydrochloric acid. Its boiling point vapour of water. Metallic mercury absorbs the vap carbonic anhydride, and nitric oxide. It is not ac holic potash dissolves it easily, the odour disappea line salt being precipitated which is decomposed w

METHYLENE, IODIDE OF. CH^2I^2. (110; cxi. 242.)—This compound is produced by t sodium; probably together with oxide of ethylene,

$$CHI^3 + C^2H^5NaO = CH^2I^2$$

The best result is obtained when 9 at. ethylate solution), and not turned brown by exposure to pulverised iodoform. On adding water to the pro as an oily liquid which must be washed with wate cium. It is a yellowish strongly refracting liquid at + 2° it solidifies to a mass of broad shining cr

Butlerow regards it as probable that the substa Ch. Phys. xxv. 311), by the action of pentachloric iodide of methylene; also the compound which Br civ. 187), by treating iodoform with alcoholic pota

Iodide of methylene is not decomposed by *potas* on applying heat, an evolution of gas immediatel explosion. *Sodium* acts in a similar manner, but *sodium-amalgam* containing $\frac{1}{8}$ of sodium is rubbed of methylene, a combustible gas is evolved, and ic with a blackish carbonaceous substance which gli gas is chiefly hydrogen, but appears to contain when it is passed into bromine, after having bee methylene and of alcohol by passing first through the bromine is afterwards treated with potash, a sm having an odour like that of Dutch liquid. Heate sealed tubes, it yields cuprous iodide and a gaseou dride, carbonic oxide, and marsh-gas, together wit homologues, but no methylene (Butlerow, Ann methylene treated with *acetate of silver* is converte lerow). With *triethylphosphine* it reacts similarl

METHYLENE, OXIDE OF. *Dioxymeth* lerow, Ann. Ch. Pharm. cxi. 242; cxx. 295.)—Th acid and methylic formate, is produced—1. By the of methylene:

$$2C^2Ag^2O^4 + 2CH^2I^2 = C^2H^4O^2 +$$

2. By the action of oxide of silver on iodide of m on acetate of methylene.—4. By the dry distillat (Heintz, Jahresb. 1861, p. 448.)

Preparation.—When 1 at. iodide of methylene is of silver, and heated, a violent explosive action tak viously triturated with twice its weight of pound under a layer of rock-oil—a slow and regular dec

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sisting of carbonic anhydride and corbonic oxide; and dioxymethylene ck of the retort, or passes over with the vapour of rock-oil into the condenses in a thin white layer, which adheres closely to the sides It is purified by pressure between paper, and washing with ether, , then with alcohol and ether, in the order here mentioned, and l of vitriol and sublimed in sealed tubes.

xymethylene forms translucent, hard, crystalline crusts having an ne structure. It is odourless at ordinary temperatures, but emits a ritating odour when heated. Tasteless. Neutral to litmus paper. vithout previous fusion. Begins to volatilise at 100°, but is not ed till heated above 150°; at about 152° it melts, and immediately to boil. A lump of it quickly heated, melts and boils at the same sity, obs. = 2·07; calc. = 2·08. It does not dissolve in water, hen merely boiled with them; but when heated with water to 100°, r several hours, it dissolves completely, forming a solution which n a vacuum, leaves a residue consisting chiefly of the unaltered oxide. es not therefore behave with water like oxide of ethylene, C^2H^4O, be regarded as the ether of the hypothetical methylene-glycol, inas- should have the composition CH^2O; but it appears rather to be the yethylene, $(C^2H^4)^2O^2$ (ii. 599).

—1. Dioxymethylene has a great inclination to take up an additional , being thereby converted into carbonic anhydride and water, and into formic and oxalic acid. It reduces the oxides of silver and ed with them. *Nitric acid* and a mixture of *sulphuric acid* and *um* converts it into carbonic anhydride and water. Inclosed together um in a sealed tube containing oxygen, it oxidises slowly at ordi- gher temperatures, yielding carbonic acid and water. Heated to hours in sealed tubes with water and *peroxide of lead*, it yields ate of lead. In the preparation of this compound by the process f it appears to be oxidised by oxygen derived from the oxalate of ume of carbonic evolved is greater than that of the carbonic oxide ual according to the above equation); and towards the end of the id sublimes in crystals: $C^2H^4O^2 + O^2 = C^2H^2O^4 + H^2O$.—2. With *horus* it yields iodide of methylene, and is at the same time partially hen *ammonia*-gas is passed over pulverised oxide of methylene, heat y liquid is separated, and a volatile crystalline substance is formed operties.—4. It is decomposed by heating with *lime-water* or dilute mate and methylenitan (p. 1008).

E, SULPHIDES OF. (A. Husemann, Ann. Ch. Pharm. cxxvi. *hylenic sulphide*, CH^2S, is obtained by heating monosulphide ide of methylene, as a loose white insoluble powder. When heated nverted into a sublimable body, consisting of *dimethylenic* S^2, and probably identical with the compound which Girard c. 306) obtained by the action of nascent hydrogen (from zinc id) on sulphide of carbon. When obtained as above, it crystallises prisms having an intolerable odour of onions, melting at a tem- °, but volatilising in considerable quantity at a much lower tem- ringly soluble in most liquids, most readily in *benzene* and *sulphide* ms crystalline double salts with the *chlorides of mercury, gold,* with *nitrate of silver*, and unites directly with *iodine*, forming a nd, but not with *bromine*. *Fumic nitric acid* attacks it violently, mes and forming a compound which crystallises in acute rhombohe- y consists of dimethylenic oxysulphide, $\left.\begin{matrix}CH^2\\CH^2\end{matrix}\right\}S^2O^2$ (Husemann). resembles that just described in its behaviour with solvents (from es in quadratic prisms), and in forming crystalline compounds with d the chlorides of gold and platinum; it was dissolved without de- rochloric acid, slightly also by dilute sulphuric acid; when heated ric acid it decomposed, with separation of sulphur. Hot nitric completely, with formation of sulphuric acid, carbonic acid, and

E, SULPHOCARBONATE OF. $\left.\begin{matrix}(CS'')\\CH^2\end{matrix}\right\}S^2$.—Separates on gently solution of dioxymethylene with sulphocarbonate of sodium, as a norphous, inodorous powder, insoluble in water, and converted by

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fuming nitric acid into methyl
metholic acid; Liebig's methio

METHYLENE-PHOSPH

METHYLENE-SULPH

METHYLENITAN. C
saccharine substance somewh
acid, by the action of strong b

$4C^2H^4O^2$
Dioxymethyle

Dioxymethylene dissolves w
lime-water be gradually adde
colour, the liquid remains neu
evaporated in a vacuum, yield
with crystalline calcic formate
methylenitan dissolves, and re
(containing a little lime) hav
caramel. The solution has a
decolorised again by acids; i
when heated with it; has no
yeast. When heated for seve
oily bitter compound, probabl
in water, partially volatilised
barium when saponified by ba

METHYLENE-STANI
See TIN-RADICLES, ORGANIC.

METHYL-ETHYL-AM

METHYL-ETHYL-AM

METHYL-ETHYL-AM

METHYL-ETHYLATE
gether with dimethylate of et
ethylic alcohol with sulphuric

METHYL-ETHYL-CA

METHYL-ETHYL-CO

METHYL-ETHYLIC

METHYL-ETHYL-PH

METHYL-ETHYL-UR

METHYL-HEPTYLIC

METHYL-HEXYL, or
electrolysis of a mixture of a
tity only, probably because œn
acid. On rectifying the resul
to consist chiefly of methyl-
(Wurtz, Ann. Ch. Phys. [3]

METHYLIA. Syn. wit

METHYLIDENE-CON

METHYL-IRISINE.
of methylic sulphate on chino

METHYL-LACTIC A

METHYL-LUTIDINE

METHYL-MALIC AC

METHYL-MORPHIN

METHYL-NICOTINE

METHYL-NITROPHE

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NITROSALICYLIC ACID. See SALICYLIC ETHERS.

ŒNANTHYL. $C^8H^{16}O$ = $CH^3.C^7H^{13}O$. (Städeler, J. pr. Chem. compound acetone, isomeric with caprylic aldehyde, obtained by dise of equivalent quantities of acetate and œnanthylate of sodium; also, heptylic or octylic alcohol, by distilling ricinoleate of potassium or cess of caustic alkali (see HEPTYL, HYDRATE OF, p. 144). It is a thin, ral liquid of specific gravity 0·817 at 23°; boiling between 171° and ell recalls that of oil of rue; taste similar, and slightly burning. It ots on paper; does not turn acid on exposure to the air, even in contact black; burns with a bright yellow flame. It is insoluble in *water*, but roportions with *alcohol* and *ether*; mixes with *sulphuric acid*, evolving ecipitated from the yellow solution by water, apparently unchanged. *potash*, *silver-oxide*, and *chromic acid*, it behaves like caprylic aldehyde *pentachloride of phosphorus*, it yields chloride of octylene, $C^8H^{16}Cl^2$. nn. Ch. Pharm. cvi. 269.)

ŒNANTHYLIC ETHER. Syn. with HEPTYL-METHYLIC ETHER

OXALIC ACID. See OXALIC ETHERS.

OXAMIC ACID. See OXAMIC ETHERS.

PARABANIC ACID. See CHOLESTROPHANE (i. 926).

PARATARTARIC ACID. See TARTARIC ETHERS.

PHENIDINE. Syn. with ANISIDINE (i. 304).

PHENYLAMINE. See PHENYLAMINES.

PLUMBIDES. See LEAD-RADICLES, ORGANIC (iii. 603).

PHOSPHINES and **PHOSPHONIUMS.** See PHOSPHORUS-ANIC.

PHOSPHORIC ACID. See PHOSPHORIC ETHERS.

PHOSPHOROUS ACID. See PHOSPHOROUS ETHERS.

PIPERIDINE. See PIPERIDINE.

PIPERYL-CARBAMIDE. See CARBAMIDES (i. 757).

SALICYLIC ACID. See SALICYLIC ETHERS.

SELENIC and **-SELENIOUS ACIDS.** See SELENIC and SELENIOUS

STANNETHYL. See TIN-RADICLES, ORGANIC.

STIBINES. See ANTIMONY-RADICLES, ORGANIC (i. 344).

STRYCHNINE. See STRYCHNINE.

SULPHURIC ACID. See SULPHURIC ETHERS.

SULPHOCARBONIC ACID. See SULPHOCARBONIC ETHERS.

SULPHOPHENIC ACID or **SULPHANISOLIC ACID.** d by dissolving anisol in strong sulphuric acid (see i. 305).

TARTARIC ACID. See TARTARIC ETHERS.

-THIOSINAMINE. See THIOSINAMINE.

URAMINE. $C^2H^7N^3$. (Dessaignes, Compt. rend. xxxviii. 839.)— d by heating an aqueous solution of creatine or creatinine with mer- arbonic anhydride is then evolved without a trace of ammonia; the oxide artly reduced; and oxalate of methyluramine is obtained in crystals:

$$\underset{\text{reatine.}}{C^4H^9N^3O^2} + O^3 = \underset{\substack{\text{Oxalate of Methyl-}\\\text{uramine.}}}{(C^2H^7N^3)^2.C^2H^2O^4} + 2CO^2 + H^2O$$

$$\underset{\text{Creatine.}}{2C^4H^7N^3O} + O^3 = (C^2H^7N^3)^2.C^2H^2O^4 + 2CO^2.$$

of oxide of mercury is too small, the crystals of oxalate of methyl- ixed with crystals of creatine; but when a sufficient quantity of is used, the oxalate of methylamine is obtained in large quantity and creatine. To separate it completely, the solution must be repeatedly cohol and evaporated. It may also be produced by treating creatine of lead and sulphuric acid; but this method does not yield so pure a preceding. (Dessaignes, Compt. rend. xli. 1258.)

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Methyluramine is obtained in the free state by hea
excess of pure milk of lime, and evaporating the filtrat
body having a crystalline surface, due perhaps to ab
deliquescent. Its taste is caustic and ammoniaca
volatilises completely, exhaling a strong odour of burn
Methyluramine contains the elements of urea and of
(Dessaignes):

$$C^2H^7N^3 + H^2O = CH^4N^2O$$

It may also be regarded as formed from 2 at. ammoni

by 1 at. cyanogen and 1 at. methyl respectively: C^2H

Traité, iii. 941.)

Methyluramine heated with baryta-water is decom
an odour of sea-water. It eliminates ammonia fro
temperatures. With the chlorides of barium and
cipitates, which are soluble in a large quantity of w
With sulphate of aluminium and ferric chloride,
dissolve in an excess of the precipitant. It precipita
mercury; forms a whitish-yellow precipitate with nitr
and chloride of silver.

Methyluramine combines with acids, forming cryst
alkaline reaction, and when heated with caustic p
alkaline vapours consisting of ammonia and meth
chlorate, and *nitrate* may be easily obtained by decor
responding calcium-salts.

The *chloroplatinate*, $2(C^2H^7N^3.HCl).PtCl^4$, is obtain
tion of the hydrochlorate with platinic chloride, in spl
which, when redissolved and recrystallised by cooling,
arranged in parallel groups. The salt when calcined e

The *oxalate*, prepared as above, forms flattened pri
containing $(C^2H^7N^3)^2.C^2H^2O^4.2H^2O$. It gives off its
is very soluble in water, has a disagreeable taste, and
Heated on platinum-foil, it exhales the same odour as

METHYL-UREAS. See METHYL-CARBAMIDES,

METHYL-XANTHIC ACID. See XANTHIC

METOLUIDINE. Syn. with MELOBENZYLAMIN

METHYSTICIN. A crystalline substance obt
of *Piper Methysticum* (see KAWA, p. 445).

MEZEREUM-SEEDS. M. Martius (Arch.
3 lbs of mezereum-seeds (*Semen coccognidii*), betw
vesicating oil, and about 2 drms. of a substance wh
white cauliflower-like masses.

MIARGYRITE. A sulphantimonite of silver,
Bräunsdorf, near Freiberg in Saxony, associated with
It forms thick tabular, pyramidal, or short prismatic
clinic system. Ratio of axes $a : b : c : = 0{\cdot}3565 : 1 :$
$= 81° 36'$; $\infty P : \infty P = 39° 38'$; $oP : [P\infty] = 1($
deeply striated. Cleavage parallel to $\infty P\infty$ and [P
Specific gravity = 5·2 to 5·4. The crystals are opaqu
lustre and iron-black colour; thin splinters appear
Streak dark cherry-red. Fracture subconchoïdal. V
to H. Rose (Pogg. Ann. xv. 469), 21·95 per cent.
silver, 1·06 copper, and 0·62 iron (= 99·17); the for
antimony and 35·9 silver. In an open tube it me
anhydride, and yields a sublimate of antimonious oxid

The *Hypargyrite* of Breithaupt contains, according t
and is probably a variety of miargyrite. (Dana, ii.

MIASCITE. A granular slaty rock consisting
sometimes with quartz, albite, and hornblende.

MICA. The generic name of a number of miner
Phlogopite, and Biotite, distinguished by a more or
called *micaceous*. They are usually divided optically
but in reality they are all biaxial, and apparently trimet

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een the optic axes is small, not amounting to 5°, while in others, viz. , it varies between 45° and 55°.

micas may be divided into potash-micas, containing little or no e being again subdivided into those which contain lithia, and those from that alkali; and magnesia-micas, containing for the most part per cent. of magnesia. The micas which do not contain magnesia are the optic angle of the axes is the largest: hence they are commonly s biaxial micas.

even of the same subdivision, present such differences in chemical least, according to the analyses that have hitherto been made of them), an easy matter to bring them under general formulæ. According to rg, however, they may be represented, with considerable approach to lows, M denoting a mon-atomic, and R a sesqui-atomic metal:

-mica . . . . . $2M^2O.3SiO^2 + n(2R^2O^3.3SiO^2)$
sia-mica . . . . . $2M^2O.SiO^2 + n(2R^2O^3.3SiO^2)$

these formulæ, the magnesia micas are orthosilicates, both terms of the being reducible to the form M^4SiO^4, whereas, in the formula of the only the second term can be thus reduced, the first containing 2 at. on.

I. Potash-Mica.

a. *Not containing Lithia.*

. *Common, Oblique* or *Biaxial Mica. Muscovy glass. Verre de Muscovie.* art.—This mineral occurs in trimetric forms, usually hemihedral, and clinic aspect. ∞P : ∞P = 120°. Cleavage basal eminent; occasionally gles to two opposite sides of oP; separating in fibres. It also forms servable by internal markings or by polarised light; face of composition Folia sometimes aggregated in stellar or plumose groups. Hardness = cific gravity = 2·75 to 3·1. Lustre more or less pearly. Colour white, n, and violet-yellow, sometimes brown and dark olive-green; colours e axial and diametral directions. Streak uncoloured. Transparent to hin laminæ, flexible and elastic. Very tough. Sectile. Biaxial; angle xes varying from 45° to 75°.

l, it gives off more or less water, which exhibits with glass the reaction acid. Melts before the blowpipe more or less easily, to a grey or fied glass. Gives with fluxes the reactions of silica and iron (sometimes

. From Litchfield in the State of Maine: white (Smith and Brush). f Carlow, Ireland: grey; angle of axes = 72° 18′ (Haughton).— valley, County of Wicklow: angle of axes = 70° 4′; specific gravity = ton).—*d.* Ceux, near St. Etienne in the Vosges: greyish-white, reddish light; specific gravity = 2·817 (Delesse).—*e.* Zsidovacz, in Hungary: gravity = 2·817 (Kussin).—*f.* Schwarzenstein, Zillerthal (chrome-): green (Schafhäutl).—*g.* Utö, Sweden: golden-yellow (H. Rose). Siberia (H Rose).

	a.	*b.*	*c.*	*d.*	*e.*	*f.*	*g.*	*h.*
. .	. .	. .	. .	. .	. .	0·35	0·53	0·28
. .	44·60	44·64	44·71	46·23	48·07	47·95	47·50	47·19
. .	36·23	30·18	30·13	33·03	38·41	34·45	37·20	33·80
e . .	. .	. .	. .	. .	. .	3·95		
. .	1·34	6·35	4·69	3·48	. .	1·80	3·20	4·47
xide .	. .	. .	. .	. .	. .	. .	0·81	2·58
. .	0·37	0·72	0·90	2·10	. .	0·71	. .	
. .	0·50	. .	1·09	. .	. .	0·59	. .	0·13
. .	6·20	12·40	9·91	8·87	10·10	10·75	· 0	8·35
. .	4·10	. .	1·27	1·45	. .	0·37	. .	
. .	5·26	5·32	6·22	4·12	3·42	. .	2·63	4·07
	98·60	99·61	98·92	99·28	100·00	100·92	101·47	100·87

ca is a constituent of granite and its associate rocks, gneiss, syenite and occurs also in more recent aggregate rocks; also in imbedded crystals nestone, wacke, trachyte and basalt. Coarse lamellar aggregations of he matrix of crystals of topaz, tourmaline, and other mineral species.

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Mica is sometimes altered by the action of water, losi
and often some portions of its alkalis and ferric oxide.
to be a mica thus altered; also, perhaps, *Damourit*
found at Stonagwyn, near St. Just in Cornwall, contai
per cent. silica, 40·11 alumina, 2·43 ferric oxide, 4·1
water; and *Sericite* (*q. v.*).

β. Containing Lith

Lepidolite. Trimetric, often occurring in oblique,
119° to 120°; also in coarsely granular masses consis
basal, highly eminent. Hardness = 2·5 to 4. Spec
pearly. Colour rose-red, violet-grey, yellowish, w
apparent optic axes = 70°—78°.

When heated, it gives off water exhibiting a stro
Heated before the blowpipe, either alone or with a
sulphate of potassium, it colours the flame red (in the
from the presence of boron, C. Gmelin). Melts easil
the reactions of iron and manganese. It is attacke
and sulphuric acid; after fusion, the finely pulveri
acid.

Analyses: a. From Zinnwald in the Erzgebirge (
locality (Rammelsberg); *c.* Altenberg in the E
(Turner); *e.* Rozena in Moravia (Rammelsberg
g. Chursdorf in Saxony (C. Gmelin); *h.* Juschakov

	a.	*b.*	*c.*	*d.*
Fluorine . . .	6·35	7·47	1·43	4·5
Chlorine . . .	0·21	. .	0·40	. .
Silica . . .	42·97	46·52	47·01	50·8
Alumina . . .	20·59	21·81	20·35	21·3
Ferric oxide . .	14·18	4·68	14·34	10·0
Ferrous oxide . .	. .	6·80		
Manganic oxide . .	. .	. .	. .	. .
Manganous oxide .	0·83	1·96	1·53	
Lime . . .	. .	. .	. .	. .
Magnesia . . .	. .	0·44	. .	. .
Potash . . .	10·02	9·09	9·62	9·8
Soda	1·41	0·39	. .	. .
Lithia . . .	1·60	1·27	4·33	4·0
Water . . .	0·22	. .	1·53	
Phosphoric acid . .	. .	0·13	. .	. .
	98·38	100·56	100·54	100·7

The lithia-micas contain a larger proportion of ma
ing division. Rammelsberg restricts the name lepi
from iron.

2. MAGNESIA-MICAS.

The micas of this division, mostly of dark green, br
about 40 per cent. silica, often a large quantity of ir
constituent, sometimes to the amount of 30 per cent.

Potash is also present, but in comparatively small
almost always contain fluorine, and frequently water.
for the most part with difficulty, to grey or blackish
a strong iron-reaction. They are attacked with dif
pletely decomposed by sulphuric acid, the silica rema
with white colour and mother-of-pearl lustre.

Phlogopite. *Rhombic Mica.*—Trimetric, occu
prisms, with biaxial refraction. ∞P : ∞P = 120°.
white or colourless and different shades of brown. C
of apparent optic axes, 5° (or less) to 20°.

Analyses: a, b, c. From Edwards, St. Lawrence Co
brown; *b.* and *c.* colourless, with silvery lustre (C
granular lime-stone: greenish; specific gravity, 2·746

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; fuses easily before the blowpipe to a white enamel, and colours the eitzendorff).—*f.* Sala in Sweden (Svanberg).

	a.	*b.*	*c.*	*d.*	*e.*	*f.*
. .	4·20	trace	trace	0·22	3·30	0·62
. .	40·14	40·36	40·3	37·54	41·30	42·64
. .	17·36	16·45	16·08	19·80	15·35	13·05
. .	trace	trace	trace	1·80	1·77	7·90
. .	. .	. .	. .	0·10	. .	1·06
. .	28·10	29·55	30·25	30·32	28·79	25·98
. .						
. .	10·56	7·23	6·07	7·17	9·70	6·03
. .	0·63	4·94	4·39	1·00	0·65*	
. .	. .	0·95	2·65	1·51	0·28	3·17
	100·99	99·48	99·80	100·16	101·14	100·45

* With lithia.

ca is especially characteristic of granular limestone. The phlogopites change, losing their elasticity and becoming pearly in lustre, often ots, as if from the hydration of the oxide of iron. In some cases, an ite has been observed.

agonal Mica. Uniaxial Mica.—Probably trimetric, formerly sup- gonal. Occurs usually in tabular prisms with basal cleavage, highly n also in foliated masses. Refraction biaxial; angle between the axes ardness = 2·5 to 3. Specific gravity = 2·7 to 3·1. Lustre pearly, on the terminal faces of the prism. Colours various, as in the pre- usually dark green, brown, or nearly black; sometimes white or k uncoloured. Transparent to opaque. Thin laminæ, flexible and

From Lake Baikal in Siberia (H. Rose). — *b.* Vesuvius: yellowish d (C. Bromeis).—*c.* Monroe, New York: dark green (v. Kobell).— rnace, near Monroe: dark green (v. Hauer).—*e.* Schwarzenstein in green (chrome-mica) (Schafhäutl).—*f.* Eifel: pinchbeck brown From the protogyne of the Alps: dark green; specific gravity = 3·127. n before the blowpipe: perfectly decomposible by hydrochloric acid Abberfoss in Finland (Svanberg).

	a.	*b.*	*c.*	*d.*	*e.*	*f.*	*g.*	*h.*
. .	0·65	. .	0·50	. .	trace	. .	1·58	0·29
. .	42·01	39·75	40·00	40·21	47·68	43·10	41·22	39·44
. .	16·05	15·99	16·16	19·09	15·15	15·05	13·92	9·27
. .	4·93	8·29	7·50	7·96	5·72	25·84	26·90	37·39
. .	. .	. .	. .	. .	5·90			
de .	. .	. .	. .	. .	1·05	. .	1·09	2·57
. .	25·97	24·49	21·54	21·15	11·58	10·82	4·70	3·29
. .	. .	0·87	. .	1·55	. .	0·81	2·58	0·75
. .	7·55	8·78	10·83	5·22	7·27	4·62	6·05	5·06
. .	. .	. .	. .	0·90	1·17	0·82	1·40	
n .	. .	0·75	3·00	2·89	2·86	1·50	0·90	
. .	. .	. .	0·20	. .	. .	1·03		
matter	. .	0·10						
	97·16	99·02	99·73	98·97	98·38	103·59	100·34	98·06

s perhaps identical with the preceding; indeed no definite line of be drawn between them. Since the percentage of iron decreases, , as the magnesia increases, part of the iron must be present as ferrous elsberg.)

tite occurs in brilliant well-defined crystals; that from Greenwood ork, in large very regular rhombic prisms, and tetrahedral pyramids. altered to rubellan and steatite; it has also been observed altered to Tyrol.

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For further details respecting the optical prope
logy, ii. 217, and for a full discussion of the ch
Mineralchemie, pp. 656–672.

MICA-SLATE. A rock similar in constituti
foliated structure.

MICHAELITE. A white, fibrous, pearly v
St. Michael in the Azores.

MICROBROMITE. A variety of bromochlo

MICROCLIN. A variety of orthoclase from
however, regards it as triclinic, although the angl
cleavage differs by only 22′ from 90°. According
miascite (p. 1009) consists of microclin.

MICROCOSMIC SALT. Ammonio-sodic
used as a flux in blowpipe experiments. (See BLO

MICROLITE. A variety of pyrochlore fr
Massachusetts. (See PYROCHLORE.)

MIDDLETONITE. A fossil resin found i
collieries near Leeds, and at Newcastle. It is br
nearly insoluble in alcohol, ether, and oil of turp
carbon, 8·01 hydrogen, and 5·56 oxygen. (Johns

MIEMITE. Syn. with DOLOMITE.

MIESITE. Syn. with PYROMORPHITE.

MILK is the liquid secreted by the mammary
Mammalia. Its colour is generally white, often b
it is opaque, has little or no smell, a slightly swee
reaction. The specific gravity of milk varies be
the average specific gravity of human milk = 1
—1·04648). (Vernois and Becquerel.)

Chemists differ as to the reaction of fresh milk. Be
ascribe an acid reaction to normal milk; Simon a
consider that when it is acid, that quality is due ei
to stand before testing, or to disease. Molescho
cow's milk (stall-fed) which had just been drawn w
different specimens of human milk, some diseased,
neutral, and the rest alkaline. Rattenmann,
two acid, and that probably owing to some ex
out of 94 specimens of fresh cow's milk, Rueff
of mare's milk, 19 acid; sheep's milk as often aci
milk of carnivorous animals (dogs and cats) alw
dog's milk coagulates by heat like turned cow's
always acid (15 cases). The reaction of the milk
upon the nature of the food. According to
stall-fed animals is always acid, and becomes alk
out to grass. Hermbstädt found milk that had
Fraas caused a cow to be milked six times in a d
feebly alkaline; after an interval of 24 hours, the c
portion of the milk was found to be alkaline, the
ever, found the milk of a cow which had not bee
some experiments the milk was as often acid as alk
ing was more often acid than evening milk.

When milk has stood for some time, a thick y
collects on its surface (*cream*); while the lower
poorer in fat, and at the same time increases in sp
temperature be not too low, the milk, when previou
tion, but remains homogeneous for a time. It then
than boiled, and more rapidly if the temperature be
charged with electricity. Milk is immediately coag
evaporated, a dense white film forms on its surface.

The spontaneous coagulation of milk appears to
undergoing acid fermentation, and thus yielding
casein. A solution of pure casein is not precipitat
rendered alkaline by addition of alkali is not coagu
however, coagulated alkaline milk in ten minutes
was still alkaline after the precipitation of the casei

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der the microscope, fresh milk appears as a clear liquid in which the *-globules* are suspended. They vary considerably in size (diameter = 2" and 0·0018"), and rarely in fresh milk attain the diameter of 0·0038". ddition of reagents, they appear merely as globules of fat.

proved the existence of an external envelope; he added acetic acid to the d that the shapes of the globules were thereby distorted. Mitscherlich globules were not dissolved when milk was shaken up with ether, which en the case if they were a simple emulsion of fat; if, however, caustic potash f potassium, which dissolves the envelope, was previously added, the fat solved by ether. Lehmann also remarked that the surface of the ilk merely treated with ether, appeared less transparent, turbid, and f it had been coagulated; the ether took up the fat on the addition of sodium. Moleschott acted on the coagulum, obtained by adding lk, with acetic acid, and extracted the fat with ether; there remained n fat envelopes in the form of little vesicles, which he was able to fill eal solution of chlorophyll; they contained no fat. From this he not only istence of the fat envelopes, but concluded also that they are organised. *Physiol. Heilk.* xi. p. 696–708.)

nd of morphological elements, the so-called *granular bodies* (*corps lostrumkörperchen*), occurs in the colostrum (the milk secreted during r three days after parturition). They consist of irregular conglomerations fat-vesicles, united by an amorphous and somewhat granular substance. r = about 0·0111" (Henle), but varies between 0·0063" and 0·0232". ich more easily dissolved by ether than that of milk-globules. They are potash or by acetic acid; iodine-water imparts an intensely yellow m; hence they consist of very small globules of fat imbedded in an ubstance. They are found in human milk up to the third or fourth day th, sometimes, however, as late as 20 days after. Moleschott found in of cows, together with milk-globules, five different kinds of granular bules (*loc. cit.*).

olostrum is at first yellow, on the first and second day; it then becomes n the third or fourth day becomes white. According to G. Veit, in the olostrum to milk, the milk-globules (which cohere in the colostrum) lose and the largest (above 0·00166" in diameter) disappear, when a richer rmed, and albumin ceases to be present in the milk. The secretion of begins on the fourth day at the earliest, but generally between the sixth .

-cells and *mucus-globules* are of only accidental occurrence in milk.

rs only when the milk contains blood.

infusoria or *plants* low in the scale of organisation are found in blue nd in that of women (Vogel). T. Fuchs ascribes the blue colour of nfusorium which he calls *Vibrio cyanogeneus*; Bailleul ascribes it to a

—The analysis of milk is attended with considerable difficulties. It is ible to obtain a perfectly dry residue by evaporation, since the casein, n fat, forms crusts which are impermeable to steam, and these are often , thereby occasioning loss. The casein is not completely precipitated by rt remaining in solution; neither does dried casein part with all its fat

may be approximately estimated by evaporating milk on a water-bath or st to dryness, adding acetic acid, and extracting the dried residue succes- her, alcohol, and water (Scherer and Dumas)—or one-fifth of its weight ypsum is stirred up with the milk before evaporation, whereby spirting is asein becomes insoluble in all solvents, and the dried residue is rendered ssable. The *fat* may then be extracted by ether and alcohol. The solid ermined by evaporating 1 to 3 grammes of milk in vacuo, or in a water- ng the residue in an air-bath, or in vacuo at 120°. In order to determine ried substance must be ignited in oxygen gas. (Haidlen.)

e milk for this purpose must not be acid. To determine the sugar, the e employed which is left when casein is precipitated by sulphate of chloride of calcium, and the excess of base precipitated by potash; or the act obtained in Haidlen's method of estimating casein may be used. The gar is determined by Fehling's sugar-test, or by polarised light.

er (J. pr. Chem. lxxxiv. 145; Jahresb. 1861, p. 873) evaporates the -filters nearly filled with pure sand or pulverised quartz, previously well- hydrochloric acid and ignited. The filters are first dried by exposing, rent of air at 110°, on a stand of peculiar construction which allows the

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entire surface of the paper to be exposed to the
sample of milk is then poured upon them, taking
over the surface of the sand and not to wet the ou
is then exposed in the drying chamber to a curren
escaping air no longer deposits moisture, after
raised to 105° and kept at that point for half an
cool for an hour over chloride of calcium, and
amount of solid constituents in the milk. To
drenched with anhydrous ether in funnels closed
their beaks provided with spring-clamps; the eth
allowed to run by opening the spring-clamps, this op
filters are rinsed two or three times with ether, th
the quantity of fat. The sugar and soluble sal
lar manner with warm water (about 90 c. c.), an
removed is determined by again drying and weighi
in the aqueous solution is then determined by t
tion, and the difference gives the amount of solu
of fat, sugar, and soluble salts, deducted from
previously determined, gives the quantity of inso
however, slightly soluble). To determine the tota
a known quantity of the milk (slightly acidulate
dryness over the water-bath and the residue is co

The following are analyses of human milk at
also of the milk of different animals.

	Vernois and Becquerel. *Normal.*	Simon.*
Water	889·08	883·6
Sugar	43·64	48·2
Casein and extractive matters	39·24	34·3
Butter	26·66	25·3
Salts (ash)	1·38	2·3
Solid constituents	,,	116·4
	1000·00	

	L'Heritier.	Chevallier and Henry.
Water	870·6	879·8
Sugar	63·4	65·0
Casein	9·5	15·2
Butter	52·0	35·5
Salts	4·5	4·5
Solid constituents	129·4	120·2

	Chevallier and Henry. *Ewe.*	Payen. *Mare.*	Si *H colo*
Water	85·62	89·33	82
Sugar	5·00	8·75	7
Casein	4·50	1·62	4
Butter	4·20	0·20	5
Salts	0·68	†	
	100·00	10·000	17

Ewe's milk is thus the richest of all milks; that
Human and cow's milk stand pretty close to one
easily substituted for the first; cow's milk is, how
sugar. The milks of the ass and mare are the poo
quantities of butter and of casein, but are proportio
the carnivora differs from that of the herbivora by
by a greater proportion of fat.

* Mean of fourteen analyses made at different periods, with
† The insoluble salts were weighed with the casein, the a
about 0·4 per cent.
‡ Kopp and Will's, Jahresb. 1856, 564.

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Constituents of Milk.

i. 810). Simon found 4·0 per cent. casein in human colostrum, and 2·15 e milk six days after delivery. Milk varies in composition at different ay. In the case of two cows fed with hay, oat-straw, beet-root, oil-cake, , the milk obtained in the morning (4 A.M.) contained 2·56 and 2·51 per nid-day, 2·23 and 2·38 respectively. In another case, the milk contained, , 2·24 and 2·25; at mid-day, 2·37 and 2·36; in the evening (7 P.M.), 2·70 cent. casein respectively (Struckmann and Bödeker). Heynsius portion of cow's milk richer in casein than the last portions. Accord- is and Becquerel, the amount of casein in human milk varies directly ntity yielded; in cow's milk, inversely as the quantity. The milk of ains about 0·3 per cent. more casein than that of blondes. Women of tion yield almost normal milk, while those of vigorous constitution yield casein. In *acute diseases*, out of 19 cases, the average percentage of 40 per cent. (3·291—5·671); and in 27 cases of *chronic diseases*, 3·257 1—3·989) (Vernois and Becquerel). The milk of nurses between rs old contains 5·574 per cent. casein and extractive matter; 20—25, ; 25—30, 3·653 per cent.; 30—35, 4·233 per cent.; 35—40, 4·207 per cent. ous substance has been met with in milk, and especially in colostrum, agulated by rennet, but is precipitated by boiling. This is supposed to G. Veit remarked that the colostrum of women, up to the third day coagulated entirely or in part on heating. It afterwards lost this pro- trate obtained from the acid colostrum of the cow, after adding chloride e no turbidity with acetic acid, but yielded a precipitate with tannin, nd by heat; on adding ammonia and boiling, an abundant precipitate t the liquid remained unchanged when treated in the same way with Hence albumin must have been present (Moleschott). Vernois and und, in the milk of the buffalo-cow and of the goat, 1·3 per cent. albumin. nd 0·5 per cent. albumin in cow's milk previously coagulated with acetic ecipitated by boiling; but if the milk was previously boiled and coagu- acid at 40° C., no turbidity was produced in the filtrate by acetic acid Albumin is also found in milk in inflammatory diseases of the mammary nen it contains blood and pus. Nevertheless, it must be remarked that pared a kind of casein from normal milk, which coagulated by heat; ilk sometimes becomes thick on heating, but returns to its previous state Dumas.)

t of human milk has not been examined qualitatively with any degree The butter of cow's milk has however been more particularly investi- milk-fat is a colourless or very pale yellow substance, solidifying at pon the temperature rises to 32°. It is soft and sticky above 18°. ·9 pts. of boiling alcohol of specific gravity 0·822. It readily becomes sure to the air, yielding volatile fatty acids, and then decidedly reddens y be completely saponified, and then yields, together with glycerin, mar- pric, caprylic, caproic, and butyric acids, or instead of the two last, Lerch), or, according to Heintz, oleïc and butic ($C^{28}H^{46}O$, melting-point tearic, palmitic, and myristic acids (Chevreul, *Sur les Corps gras*, is, Ann. Ch. Pharm. xlii. 46, &c.; Heintz, Ann. Ch. Pharm. lxxxviii. . Ann. xc. 137). Bromeis reckons the composition of butter according ies of acid found = 68 per cent. margarin, 30 per cent. elain, and liar butter fat; but the components of butter seem to vary considerably.

Percentage of Fat in different kinds of Milk.

*Human.**

Simon).
2—3·345 (Clemm).
lier and Henry).
36—5·642) (Vernois and
).

Cow.

Simon).
lier and Henry).

3·90 (Boussingault).
4·38 (Poggiale). (Average of 10 analyses.)
8·4 (Buffalo cow.) } (Vernois and
3·61 (Paris cow.) } Becquerel).

Mare.

6·952 (Clemm).
2·44 (Vernois and Becquerel).

ne days, and twelve days after birth respectively.
(Ann. Chem. Pharm. cviii. 64) found in the milk from the enlarged breast of a nous amount of 28·5 per cent. fat.

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Ass.

1·21 (Simon).
1·29 (Peligot).
1·85 (Vernois and Becquerel).

Ewe.

4·20 (Chevallier and Henry).
5·13 (Vernois and Becquerel).

Sow.

1·93 (H. Scheven).

Simon found 5·00 per cent. fat in human colostr
2·60 per cent. in the colostrum of the cow. Acc
brunettes contains 5·63—6·48 per cent. fat, while
4·05. Vernois and Becquerel found the contr
age of fat varies with age; the milk of women fro
20—25, 2·821 per cent.; 25—30, 2·348 per cent.;
35—40, 2·233 per cent. It increases by nearly 0
struation. The percentage of butter varies invers
It decreases with imperfect nutrition.

Milk contains different proportions of fat accor
is obtained. The milk of a cow contained in the
2·63 per cent., and in the evening, 5·42 per cent.
has been remarked that the first portions of milk
tions, from which it is concluded that milk deposi
fat-globules adhere to the sides of the milk-passag
the udder and teats. This difference has not been
tier found the first portion of cow's milk three-fo
According to Vernois and Becquerel, the amo
during the first two months after delivery, but de
well as between the tenth and eleventh month. T
influence on the percentage of fat in milk. The
contains 3·53 per cent. fat; on sesame bran, 4·87
milk was on the whole richer in fat when the ani
animal food. In disease, Vernois and Becque
was sometimes increased, sometimes diminished.
per cent. butter. In enteritis, human milk was
in pleurisy, 2·77 per cent.; in colitis, 5·412 per
cent.; typhus, 0·909 per cent.

Sugar of Milk (*Lactin*):

Percentage of Sugar in differe

Human.

3·2—6·24 (Simon, Clemm, Haidlen).
4·364 (2·522—5·955) (Vernois and Becquerel).

Cow.

3·4—4·3 (Simon, &c.).
4·26—4·61 (Struckmann and Bödeker).
5·28 (average; Poggiale).
3·80 (Vernois and Becquerel).

Ass.

5·05 (Vernois and Becquerel).
4·5 (Simon, &c.).

Mare.

8·7 (Simon, &c.).
3·28 (Vernois and Becquerel).

The milk of brunettes contains 7·00 and 7·12 pe
5·85 and 6·40 per cent. (L'Heritier). Accordin

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ns 4·56; blondes, 4·47. Simon found 7 per cent. milk-sugar in human
e milk six days after birth, 6·24 per cent.; afterwards the quantity de-
ind of food influences the percentage of milk-sugar to a certain extent.
that it almost disappeared from canine milk when the animal was fed
meat; on substituting vegetable food, the quantity of milk-sugar
derably. Poggiale found in the milk of a bitch fed with meat
per cent. milk-sugar, but after the animal had been fed exclusively
days, only 1·82 per cent. According to the observations of Simon
s and Becquerel, rich or poor nourishment does not sensibly affect
f lactin; it varies as the quantity of milk. The milk of women from
ld contains 3·523 per cent. milk-sugar; from 20—25, 4·472 per cent.;
er cent.; 30—35, 3·953 per cent.; 35—40, 3·960 per cent. In the first
h, the quantity of sugar in the milk decreases, but it increases con-
he eighth to the tenth month (Vernois and Becquerel). The milk
in the morning 4·30 per cent. sugar; at midday, 4·72 per cent.; in the
(Struckmann and Bödeker). Heynsius found that the last
's milk contained less sugar than the first. According to Simon,
ers, the percentage of sugar does not sensibly vary in disease. Accord-
and Becquerel, this is the case only with *chronic* diseases, whereof
average amount was 4·337 per cent.; in *acute* diseases, only 3·310

uble salts of milk consist of chloride of sodium, chloride of potassium,
ates, and soda and potash combined with the casein; the *inso-*
es of calcium and magnesium, chiefly combined with casein; sulphuric
ia-salts are not contained in fresh milk. Haidlen, Scheven, and
d a little ferric oxide in milk.

Percentage of Ash in different kinds of Milk.

Human.	*Sow.*
ost chemists).	1·09 (Scheven).
-0·338) (Vernois and	
Cow.	*Ass.*
and Becquerel).	0·52 (Vernois and Becquerel).
Bitch.	*Mare.*
and Becquerel).	0·52 (Vernois and Becquerel).
ggiale).	
Goat.	*Sheep.*
and Becquerel).	0·72 (Vernois and Becquerel).

Becquerel found in the milk of women from 15—20 years old, 0·180
20—25, 0·143; 25—30, 0·146; 30—35, 0·144; 35—40, 0·106 per

cow yielded in the morning 0·83 per cent. ash; at midday, 0·72; and
78 (Struckmann and Bödeker). Heynsius found slightly less ash
in the first portion of cow's milk; but the soluble and insoluble salts
same relations to one another. The first portions contained 0·78
the last, 0·69 per cent. Vernois and Becquerel found that the
alts increased both in chronic and in acute diseases (0·173 and
; in acute enteritis, 0·174 per cent.; acute pleurisy, 0·079; typhus,

of soluble salts is generally nearly the same as if insoluble. In human
0·4—0·9 per cent. soluble salts; in cow's milk, 0·21 per cent. soluble, and
oluble salts. According to Weber's analysis, the ash of cow's milk con-
ent. chloride of potassium, 4·74 per cent. chloride of sodium, 23·46 per
6 per cent. soda (combined with phosphoric, sulphuric (?) and carbonic
ent. phosphoric acid, 17·34 per cent. lime, and 2·20 per cent. magnesia.
hosphoric acid is tribasic. Vernois and Becquerel found in the
lk 6·9 per cent. carbonate of calcium, 70·6 per cent. phosphate of cal-
nt. chloride of sodium, 7·4 per cent. sulphate of sodium, and 5·3 per
lts.

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Milk, at least that of the cow, contains *alkaline c*
with acetic acid, it evolves more gas (carbonic acid)
out acid. (Lehmann.)

The amount of *extractive matter* in milk, as well a

Lactic acid is not supposed to exist in fresh m
occasionally acid reaction to lactic or butyric acid, o

Rees found *urea* in the milk of a woman sufferin
in the milk of a woman whose urine contained no a

Free *gases*, especially carbonic acid, are always pr

Lehmann considers *albumin* to be an abnormal

Marchand found *hæmatin* dissolved in the mil

Glucose appears to pass into the milk from the
iodide of potassium and free iodine pass into the mi

Milk is coagulated by acids, alum, and various ot
and wood-spirit.

Colostrum generally forms a turbid, yellowish liq
consistence and strongly alkaline reaction. It under
than milk, and contains more solid constituents; in
casein is chiefly in excess; in human milk, lactin.
able amount. Vernois and Becquerel found in
delivery, 12·28 per cent. solid residue (4·54 per cent.
cent. lactin, and 0·16 per cent. salts). Simon f
the colostrum of a cow, and 14 to 15 per cent. in
colostrum of a cow immediately after calving, 38·4
day, 30·1 per cent.; the second day, 23·1 per cent.;
per cent.

Human milk is more bluish than cow's milk and
alkaline, and acidifies less easily than other milks.
and 1·034 (1·02561 and 1·04648, Vernois and Be
13 per cent. solid constituents. It is less easily an
the coagulum is not so gelatinous, nor so firm and
is also more digestible. Its fat contains more elai
children of both sexes discharge from the seventh
white secretion from the breast (*Hexenmilch*), either
milk, but no colostrum-globules. According to Guil
the composition of human milk.

Cow's milk has generally a pure white or yellowis
varies between 1·030 and 1·039 (Simon), 1·0302 a
on an average between 13 and 14 per cent. solid ma

Mare's milk is white. Specific gravity = between
1·0337, V. and B.). It yields 16·2 per cent. (9·57,

Ass's milk is white; sweeter than cow's milk.
and 1·035 (= 1·0346, V. and B.). Contains betw
matter (10·99, V. and B.). It readily turns acid,
mentation.

Goat's milk is white, of insipid sweetish taste an
about 1·036 (1·0325, V. and B.). Contains betw
residue (15·51, V. and B.). On coagulation, its cas

Ewe's milk is thickish, white, of agreeable tast
between 1·035 and 1·041. Contains 14·38 per cent
constituents.

Sow's milk contains between 14·51 and 11·83 sol

Canine milk is rather thick, and becomes thicker
agulate. Specific gravity = between 1·033 and 1·
27·46 solid residue. On evaporation, the latter is
solid residue absorbs much oxygen from the air. (

The milk of women confined for the first time, co
women who have had several children. The milk of
locality; that of cows in the neighbourhood of Pari
fat; of Tyrolean, Swiss and Dutch cows, between
sition of cow's milk in the first, third, fourth, fifth
the same, varying between 12·27 and 14·20 per cent
it contains 13·29 per cent. residue, 4·80 per cent. ca
cent. lactin, and 0·66 per cent. salts; in the second m
5·81 per cent. casein, 7·06 per cent. butter, 3·87 p
salts; in the eighth month, 24·73 per cent. residue,
butter, 7·67 per cent. lactin, and 1·16 per cent. salts

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of a consumptive cow yielded a large quantity of cream, but did not coagu-
y rennet or on boiling. It contained 24·97 per cent. solid residue, 10·13
ein and insoluble salts, 10·73 per cent. butter, 4·09 per cent. lactin, and

e most indigestible of all uncoagulated albuminoïds; its solubility in the
depends upon the consistence of its coagulum. Human milk is more
sted than cow's milk. Frerichs found that 2½ hours after he had fed a dog
all had disappeared from the stomach except a few flakes, very rich in
ntroduced into the stomach was instantly coagulated, and the serum was
rbed, while the coagulum formed bulky and more or less hard clots. The
milk does not begin, properly speaking, until the liquid portion has been

n has shown that the percentage of fat in milk is in no way dependent
ount of sugar in the food.
has remarked, and his experiments have been confirmed by Poggiale,
k of bitches fed exclusively on meat still contained milk-sugar, showing
formed in the organism from albuminoïds.
k contains 30 pts. unnitrogenised substances for every 10 plastic; human
unnitrogenised for every 10 plastic (Liebig). Cow's milk contains 3·78
rogen; human milk 1·59 per cent. A cow yields in 24 hours about 5½
ut 6 kgr. of milk.
ect to the generation of milk, Lehmann and others do not suppose that
nts of milk are derived directly from the blood. Neither casein nor lactin
ected in blood. The sugar of blood is fermentable. Fat might transude
od, but it is not probable that it does so; since cholesterin, which tran-
nuch facility, is not found in milk, and little if any butyrin is found in
e composition of the milk-salts also differs widely from that of the salts of

milk: adulterations.—Fresh milk ought not to change its appearance on
ır milk deposits clots, or partly coagulates on boiling. A simple instru-
a lactometer, for roughly estimating the amount of cream in milk,
structed by Banks. It consists of a glass tube having an internal diame-
imetres, and about 17 centimetres high. A circular ring scratched on the
es a capacity of two decilitres. Above this line 30 small divisions are
ndicating $\frac{1}{100}$th of the total capacity of the vessel up to the highest division
The vessel is filled up to 0° and allowed to stand for 24 hours; the thickness of
f cream may then be read off. Another method is that of Donné. He has
instrument called a galactoscope, which measures the opacity of milk;
pacity indicating more fat-globules, and thus a greater amount of butter.
f a tube with a glass plate fitted at one end, and at the other a movable
The milk is introduced by means of a small funnel, and the tube is length-
wing out the movable plate until the liquid no longer transmits the light
aced at a certain distance. The plate is then screwed in until the light of
rendered just visible. According to Donné, milk which removes the
, indicates 3·527 per cent. butter; 31°, 2·89 per cent. butter. 40° to 35° of
ope = 5 per cent. cream (poor milk); 35° to 30° = 5·10 per cent. cream
lk); 30° to 25° = 10 to 15 per cent. cream (good milk); 25° to 20° =
r cent. cream (very rich milk); and 20° to 15° indicates an exceedingly
ne last portion from the cow.
common adulterations of milk are the following:—Milk obtained the day
amed, in order to sell the cream separately; sometimes the creamed milk
h fresh milk, and about half its own volume or more of water is added to
Sometimes a colouring matter, such as brown extract of chicory, caramel,
l to disguise the bluish colour of milk thus adulterated. The colouring
ins in the serum when the milk is coagulated, and may then be detected
Flour, starch, and finely-powdered chalk are also used to adulterate milk.
readily subsides, it may then be recognised by its effervescing with hy-
id. The starch-granules may be readily detected under the microscope,
ished from the milk-globules; if a polarising apparatus be adjusted to the
ach of the granules will appear marked with a black cross. The addition
f iodine will also indicate the presence of starch, by imparting to it the
blue colour. The macerated brains of sheep and other animals are said
mes added to milk. In this case, the microscope would readily detect the
ragments of nerve and other organised structures, which are not present in
The addition of water is not so easily detected, since if cream has been
the milk, its specific gravity will increase, while the addition of water
it. It may however be detected by the galactoscope, if no starch or

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brains have been added. The milk of diseased anim
has a disagreeable taste and smell, as well as a sl
mucus globules will be detected in it under the mic
According to Baumhauer (*loc. cit.*) all determi
of milk by instruments like those above described, a
result of determinations made by his own method
milk may be regarded as adulterated with water, whi
residue per litre (or 1928 grs.—about 3 oz. troy—p
of butter in normal cow's milk is 22 grms. per litre
be regarded as creamed, when the proportion of butt
of solid matter.
Further information will be found in the followin
Gmelin, *Handb. d. Chemie*, viii. [2] pp. 246–2
Chem. 1863, ii. pp. 287–301, the same translated
Scherer, *Handwörterb. d. Physiol.* ii. 449–475; Si
1838; Vernois and A. Becquerel, *Ann. d'hygiè
femme dans l'état de santé et dans l'état de maladi
alimentaires*; Bowman, *Medical Chemistry*; Pel
Générale, 2me. ed. Paris, 1857, p. 195. See als
Jahresbericht.

MILK QUARTZ. See QUARTZ.

MILK-SUGAR. $C^{12}H^{22}O^{11}$.—Called *Lactin*
Pasteur, on the other hand, applies the term *lactos*
of milk-sugar (see p. 1022).
This compound, the saccharine constituent of mil
Bartholetti, in 1619, from whey, thence cal
and afterwards, *Galacticum Bartholetti*. It has be
Lagrange and Vogel (J. Phys. lxxii. 208), Berzel
(Ann. Ch. Pharm. lxi. 221), Vohl (*ibid.* lxx. 360),
46), Krause and Städeler (Mitth. d. naturf. G
Lieben (J. pr. Chem. lxviii. 407), Pasteur (*ibid.*
lxviii. 422), Luboldt (*ibid.* lxxvii. 282), and Bert
lx. 98); see also Gm. xv. 217; Gerh. ii. 553.
Milk-sugar has been found only in the milk of
been confounded in some cases with glucose, the p
in the blood, in the liver, and in the eggs of bi
artificially from any other compound.
It is extracted by treating milk with dilute sulp
cipitate the curd, then filtering, and evaporating th
This product is purified by treatment with animal ch
finally, according to Krause and Städeler, by rep
solution with alcohol. In some localities, especially
pared on the large scale from the whey obtained in
Milk-sugar is deposited from its aqueous solutio
exhibiting the combination $\infty\breve{P}\infty \cdot \frac{P}{4} \cdot oP \cdot 2\breve{P}\infty$. A
= 101° 41′. Ratio of axes, $a : b : c = 0{\cdot}6215 : 1$
semi-transparent, hard, and grates between the te
$C^{12}H^{22}O^{11}.H^2O$, do not give off any water at 100°
per cent. (1 at. = 5·00 per cent.) at 130°, or mor
The anhydrous milk-sugar which remains, forms a
difies in the crystalline state on cooling.
Crystallised milk-sugar is slightly hygroscopic, an
2½ pts. of boiling *water*. The saturated solution
water with excess of milk-sugar at 10°, has a d
cent. crystallised milk-sugar, and when left to evap
soon as it attains the density of 1·063 and contain
aqueous solution turns the plane of polarisation to
for the transition-tint, $[\alpha] = 59{\cdot}3°$ (Berthelot)
Poggiale, 201·9 pts. of milk-sugar produce the same
The dextro-rotatory power of a recently prepared s
the ratio of 8 : 5, than that of the same solution af
being heated. The rotatory power diminishes slow
and at the boiling heat it diminishes in two minu
sugar. (E. O. Erdmann, Jahresb. 1856, p. 671.)

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insoluble in *alcohol* and in *ether*, but dissolves readily in *distilled* ing out unaltered on evaporation.

.—1. Dry milk-sugar turns brown when heated to about 160°, without 5° gives off water, and yields lactocaramel, $C^{12}H^{18}O^{10}$. At 203° it gher temperature yields humus-like substances.—2. Milk-sugar boiled *ric acid* is converted into lactose (*vid. inf.*); the same transformation be produced by prolonged boiling with water.—3. *Strong sulphuric acid*, and *alkalis*, decompose it, especially when heated, with for- or black products.—4. Milk-sugar is easily decomposed by *oxidising* es metallic *silver* from silver-solutions (Liebig, Ann. Ch. Pharm. olution of milk-sugar mixed with potash dissolves *cupric hydrate*, lue solution which deposits cuprous oxide, even in the cold. From a *io-cupric tartrate*, it throws down a smaller quantity of cuprous oxide glucose (ii. 860). Distilled with oxidising mixtures, such as *sulphuric e of manganese*, it yields formic acid. With *nitric acid*, it forms tartaric, and a small quantity of racemic acid, and finally oxalic acid. *tric acid* or a mixture of *nitric* and *sulphuric acids* converts milk-sugar n-product called nitro-lactin, which is precipitated from the acid r, and crystallises from alcoholic solution in nacreous laminæ deton- d. (Reinsch; Vohl, Jahresb. 1849, p. 470.)

gar is heated to 100° for some hours with *bromine* and water, there is by direct addition of bromine, a brominated compound, which when ases, yields isodiglycolethylenic or lactonic acid (p. 414).

not brought immediately by *yeast* into the state of alcoholic fermen- it is left for some time in contact with yeast, fermentation gradually *heese* or *gluten* is used as the ferment, the milk-sugar is converted into l; iii. 455). Alcohol is, however, always formed at the same time, halk is added to neutralise the acid as it forms; the quantity of alcohol also as the solution is more dilute.

—Milk-sugar unites with bases, but the compounds have not been It differs from glucose, in not forming a definite compound with m. It absorbs about 12·5 per cent. *ammonia-gas*, which, however, on exposure to the air. It dissolves in strong caustic *potash*, forming m which alcohol throws down white flocks containing 12·4 per cent. ound is easily decomposed by acids, even by carbonic acid, the milk- from it unaltered. With *soda* a similar compound is formed, con- ent. soda.

solves easily in *milk of lime*, forming a solution in which alcohol pro- nd if the liquid is concentrated, throws down a white precipitate con- shed and dried, from 11·2 to 15·7 per cent. lime. *Baryta* forms a d containing 40·1 pure baryta.

ntly heated with *oxide of lead*, gives off water. On digesting the with lead-oxide, at a temperature below 50°, part of the oxide insoluble compound remains suspended, containing when dried 63·5 ide. The dissolved portion evaporated in a vacuum leaves a gummy ntaining 18·1 per cent. lead-oxide: ammonia added to the solution insoluble compound.

Milk-Sugar. Milk-sugar may be estimated like glucose (ii. 865). pt. rend. xxviii. 505) prepares the test-liquor by dissolving 10 grms. te, 10 grms. of cream of tartar, and 30 grms. caustic potash in ed water. The filtered liquid, which has a deep blue colour, is titrated he amount of pure milk-sugar required to decolorise a given volume nine the quantity of sugar in milk, it is necessary, in the first place, to and the casein (p. 1016). Milk-sugar may also be estimated by its

Products of the Transformation of Milk-sugar.

Galactose, $C^6H^{12}O^6$ (Pasteur, Compt. rend. xlii. 347). A kind of ith glucose, and bearing considerable resemblance to it, produced by ar for several hours with 4 pts. of water and 2 per cent. sulphuric with chalk, evaporating the filtrate to a syrup, and then leaving it to

llises more readily than grape-sugar, in nodules consisting of micro- ectangular prisms acuminated at the ends,—more generally of six- ed laminæ having a pen-shaped protuberance in the middle. Dextro- r the transition tint, $[\alpha] = 83·22°$ at 15°; in the recently prepared

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solution it is stronger, $[a]$ = 139·66°, but sinks to ordinary temperatures, instantly on boiling.

Lactose dissolves in *water*, does not combine with but very sparingly in cold *alcohol*.

Lactose yields with *nitric acid* twice as much mu alkaline solution it reduces as much *cupric oxide* as tact with *yeast*. If the fermentation be interrupte still contains unaltered lactose, which therefore has ther alteration during the fermentation. In this f formed as in the fermentation of cane-sugar. (P 356.)

2. Lactocaramel, $C^6H^{10}O^5$. Produced when mi 180°. It is a dark brown substance, soluble in water, combining with the oxides of lead and copper. (180; Gm. xv. 227.)

3. Gallactic and Pectolactic Acids. These Struckmann (Ann. Pharm. c. 264) to two aci oxidised in alkaline solution by cupric oxide. Both able salts, respecting the supposed composition of w

4. Nitrolactin is best prepared by treating m and sulphuric acid, and precipitating with water. It in nacreous laminæ, which detonate when heated.

MILLERITE. Native sulphide of nickel. (S

MILLINGTONIA. The bark of *Millington* remedy against fever, contains, according to R. B —besides starch, gum, sugar, fat, wax, and an iron of a bitter substance, and certain bodies described mulæ $C^{34}H^{28}O^{26}$ and $C^{14}H^{27}O^{26}$ are assigned.

MILOSCHIN. A compact chromiferous miner containing, according to Kersten (Pogg. Ann. xlvii alumina, 3·61 chromic oxide, 0·30 lime, 0·20 mag Colour indigo-blue to celandine-green. Hardness Yields water when heated in a tube. Infusible bef by hydrochloric acid. Found at Rudniak in Servia, iron ore.

MIMETESITE. *Mimetene. Mimetite. Green Kampylite, Hedyphane.*—This name is applied to s pyromorphite, consisting either of pure arsenato-ch mixtures of this compound with the corresponding analogous calcium-compounds. The crystals are combinations P . oP (*fig.* 239, ii. 739), P . ∞P . oP and P . oP . ∞P . ∞P2. Length of principal axis = 142° 7′; (lateral) = 80° 25′. Cleavage imperf ness = 3·5. Specific gravity = 7·19 to 7·35, mimete 6·9, kampylite. Lustre resinous. Colour pale yell orange-yellow (kampylite) from the presence of chr when containing much calcic phosphate (hedypha Subtransparent to subtranslucent. Sectile. Melts but less easily than pyromorphite; exhibits a crys easily reduced to lead-globules with evolution of a acid and in potash.

Analysis.—*a.* From the Azulaques mine near La needle-shaped crystals on wulfenite (Bergemann, ville, Chester County, Pennsylvania: colourless or J. [2] xx. 342).—*c.* Johann-Georgenstadt: yellow iv. 161).—*d.* Caldbeck-fell, Cumberland (Breithau *ibid.* xci. 316).—*e.* Horrhausen in Saxony (Dufr *f.* Cornwall (Dufrénoy, *loc. cit.*).—*g.* Preobrajan within, but black on the outside, from a coating of *Mineralchemie*, p. 382).—*h.* Långbanshytta, Sweden sive, greyish-white (Kersten, Schw. J. lxii. 1).— Chile: yellow, earthy. (Domeyko, Ann. Min. [4]

I. *Containing only Arsen*

	Cl.	As^2O^5.	PbO.
a.	2·44	23·06	74·96

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II. *Containing Arsenic and Phosphoric Acids.*

	As^2O^5.	P^2O^5.	PbO.		
9	23·17	0·14	74·58	=	100·28
eter-	21·19	not deter-	75·56		
od		mined		Ca^2O.	
1	18·47	3·34	76·47	0·50	= 101·19
5	22·20	0·38	74·62	=	99·85
1	21·65	0·79	73·87	=	98·62
8	19·58	2·44	76·14	=	100·54

III. *Containing Lime.*

O^5.	P^2O^5.	V^2O^5.	PbO.	CaO.	CuO.
·78	not determined	. .	51·03	14·09	
·06	5·36	1·94	68·46	8·31	0·96 = 99·50.*

is a compound of chloride of lead and pure triplumbic arsenate,

under II. are isomorphous mixtures of true mimetesite and pyro-ato-chloride of lead) represented by the formula $PbCl^2.3Pb^3(As; P)^2O^8$. erals included under III., the lead is partly replaced by calcium; the nay be nearly represented by the formula $PbCl^2.3\left[\left\{\begin{matrix}\frac{3}{4}Pb\\ \frac{1}{4}Cu\end{matrix}\right\}^3\left\{\begin{matrix}\frac{2}{3}As\\ \frac{1}{3}P\end{matrix}\right\}^2O^8\right]$.

eral from Chile appears to be hedyphane mixed with a little vanadate

ACACIA GUM. See Gum (ii. 953).

IC ACID. Syn. with Catechu-tannic Acid (i. 817).

I SPIRITUS. Acetate of Ammonium (i. 13).

This term, in its widest sense, denotes any substance not formed organic life; in its more restricted and more usual sense, it signifies solid or liquid inorganic body, formed by natural processes, without art. Minerals understood in this sense, constitute the essential part t. It is usual, however, to include under the same general denomi-stances which are evidently the remains of organised beings, chiefly ived upon the earth in former ages, *e.g.* coal, lignite, amber, and the fossil resins and bitumens. Such bodies should perhaps in strict-ils, but they are more usually classed with minerals, and described n Mineralogy.

ACIDS are acids of inorganic origin, either existing ready formed s, or formed from inorganic materials by artificial processes. The plied to the stronger acids, sulphuric, nitric, phosphoric, hydro-

ALKALI. An old name of Soda. (See Alkali, i. 115.)

BLUE. A term sometimes applied to Prussian blue when mixed substances, such as clay, heavy spar, gypsum, &c., which give it a

CAOUTCHOUC. Syn. with Elaterite (ii. 374).

CHAMELEON. Manganate of potassium (p. 818).

GREEN. Scheele's green. (See Green Pigments, ii. 914.)

INDIGO. A term applied by Keller to the blue oxide of molyb-the reducing action of tin or stannous chloride on recently precipi-d. (See Molybdenum, p. 1036.)

KERMES. Amorphous Trisulphide of Antimony (i. 330).

OIL PITCH, RESIN. (See Petroleum.)

PURPLE. Gold-purple or Purple of Cassius (ii. 938).

TALLOW. Syn. with Hatchettin (p. 14).

TURPETHUM. Mercuric sulphate. (See Sulphates.)

WATERS. See Water.

YELLOW. A term sometimes applied to the yellow oxychlorides ments (p. 556).

* deduction of 1·1 alumina and ferric oxide, 2 clay, and 1·12 water.

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MINETTE. An eruptive rock occurring in the Vosges, where it forms small veins chiefly in granite and syenite. It consists of mica (the characteristic constituent) varying in colour from brownish-black to greenish, and orthoclase imbedded in a felspathic ground-mass. It is usually fine-grained, often porphyroïdal, when the felspar crystals are well developed. The ground-mass frequently also contains greyish-green or dark green hornblende already far advanced in decomposition. The rock also contains quartz (in very small quantity), triclinic felspar, chlorite, calcspar, &c., often also crocidolite. A specimen from the Ballon d'Alsace, gave by analysis:

SiO^2.	Al^2O^3.	Mn^2O^3.	FeO^3.	CaO.	MgO.	K^2O.	Na^2O.*	H^2O.	CO^2.
56·96	12·95	0·65	7·58	4·63	6·62	4·35	2·22	1·44	1·94 = 99·34

(Delesse, Ann. Min. [5] x. 517; Jahresb. 1857, p. 705). A rock of similar constitution, from Mittershausen in the Odenwald, has been analysed by Bunsen (Jahresb 1861, p. 1068).

MINIUM. Red oxide of lead (p. 551).

MINJAC-TANKAWAN or **TINKAWAN.** A solid vegetable fat obtained from the fruit of a tree growing in Borneo and Sumatra. The principal portion of it, insoluble in cold alcohol, consists, like cacao-fat, of stearin, palmitin and olein; a smaller portion, soluble in cold alcohol, contains free stearic acid, palmitic acid, and traces of a volatile fatty acid. (E. Ruge, Jahresb. 1862, p. 506.)

MIRABELLES. See FRUIT (ii. 714).

MIRABILITE. Syn. with Glauber salt. (See SULPHATES.)

MISENITE. Acid sulphate of potassium, $KHSO^4$, occurring in white silky fibres in a hot tufa cavern near Misene. (Scacchi, Mem. Geol. sulla Campania, 1849, p. 98.)

MISPICKEL. $Fe^2As^2S^2$, *Arsenical pyrites, Arsenopyrite, Danaite, Plisian, Fer arsénical, prismatischer Arsenikkies.*—This mineral occurs in trimetric crystals, in which the ratio of the axes $a : b : c = 0{\cdot}676 : 1 : 1{\cdot}189$. Angle $\infty P : \infty P = 68° 7'$; $\frac{1}{4}P\infty : \frac{1}{4}P\infty$ in the basal principal section $= 34° 34'$. Ordinary combination $\infty P . \frac{1}{4}P\infty$. Cleavage rather distinct, parallel to ∞P. Occurs almost columnar, compact granular, or impalpable. Hardness = 5·5 to 6. Specific gravity = 6 to 6·4. Lustre metallic. Colour silver-white inclining to steel-grey. Streak dark greyish-black. Fracture uneven. Brittle. Heated in a tube, it first yields a red or brown sublimate of sulphide of arsenic, then a black sublimate of metallic arsenic. On charcoal before the blowpipe, it melts to a black magnetic bead, which sometimes exhibits the reactions of cobalt as well as those of iron. According to Berthier, when heated in a closed crucible, it gives off half its sulphur, and a fourth of its arsenic. Nitric acid decomposes it, with separation of sulphur and arsenious acid; nitro-muriatic acid, with separation of sulphur alone, which may be completely dissolved by prolonged digestion.

Analyses. *a.* Freiberg (Behnke, Pogg. Ann. xcviii. 184).—*b.* Ehrenfriedersdorf: *Plinian* (Plattner, *ibid.* lxxvii. 127, lxxix. 430).—*c.* Reichenstein (Weidenbusch, *Rammelsberg's Mineralchemie*, p. 58).—*d.* Melchiorstollen near Jauerniek in Austrian Silesia: massive (Freitag, *ibid.*).—*e.* Sala in Sweden (Behnke, *loc. cit.*).—*f.* Altenberg, near Kupferberg in Silesia: large crystals of specific gravity 6·043 (Behnke).—*g.* Rothzechau, near Landshut in Silesia: specific gravity 6·067 (Behnke).—*h.* Wettin: small twin-crystals, of specific gravity 5·365 and 5·637 (Bäntsch, Zeitschr. f. d. ges. Naturw. vii. 372):

	a.	*b.*	*c.*	*d.*	*e.*	*f.*	*g.*	*h.*
Sulphur	20·38	20·08	19·17	21·14	18·52	20·25	19·77	22·63
Arsenic	44·83	45·46	45·94	41·91	42·05	43·78	44·02	39·86
Antimony	. .	. .	. .	. .	1·10	1·05	0·92	
Iron	34·32	34·46	33·62	36·95	37·65	34·35	34·83	37·51
	99·53	100·00	98·73	100·00	99·32	99·43	99·54	100·00

Mispickel is also found in beds at Breitenbrunn and Raschau, Andreasberg and Joachimsthal; at Tunaberg in Sweden; and at Huel-Maudlin and Unanimity in Cornwall; also at Franconia, Jackson and Haverhill in New Hampshire, and several other localities in the United States. (Dana, ii. 63.)

Danaïte (ii. 303) and *Glaucodote* (ii. 846) are varieties of mispickel in which the iron is partly replaced by cobalt, to the amount of one-sixth in the former and one-third in the latter. (Dana, ii. 62.)

MISTLETOE. *Viscum album.*—The chemical constitution of this plant has been examined by P. Reinsch (Jahresb. 1860, p. 541), who has found in it two viscous substances called viscaoutchin and viscin (*q. v.*).

* With a little lithia; a trace of copper was also found.

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impure ferric sulphate found at Rammelsberg, near Goslar in the
PHATES.)

...ITE. Arsenate of copper, $2CuO.As^2O^5$. (See GREEN PIGMENTS,

...TE. Syn. with MELONITE (p. 865).

...TONE or *Moss Agate*. (See AGATE, i. 62.)

...E or *Skutterudite*. An arsenide of cobalt, Co^3As^2, found at Skutterud, Norway (i. 1042).

. Syn. with Leucopyrite or native proto-arsenide of iron, FeAs

Native titanate of iron. (See TITANIUM.)

... This term, in its strict chemical sense, denotes the smallest quantity body that can take part in any chemical reaction. Thus, as explained TOMIC WEIGHTS (i. 457–469), the molecule of water is assumed to be not $HO = 9$, because, in the great majority of cases, 18 pts. by weight smallest quantity of water that can be taken up by, or eliminated from, ments concerned in a reaction. For a similar reason, the molecule of med to be $NH^3 = 17$, and not any multiple or submultiple thereof. Chem. Soc. Qu. J. xi. 107.)

all the considerations by which the molecular weights of bodies are de- be to repeat what has already been treated in some detail in other ork, especially that above referred to (see also CLASSIFICATION, i. 1007). suffice to point out in this place that, among the purely chemical con- h enter into the determination of this point, a prominent place must he manner in which the elements of a compound are replaced by other or compound. Thus, in the four typical molecules,

$$HCl, \quad H^2O, \quad H^3N, \quad H^4C,$$

the first, viz. hydrochloric acid, must be either wholly replaced or not at water, either the half or the whole of the hydrogen may be thus re- ther fraction; and in ammonia, the substitution takes place by thirds; s, by fourths. Again, sulphuric acid is regarded as dibasic, and repre- ; phosphoric acid as tribasic, and denoted by H^3PO^4; tartaric acid as $.C^4H^2O^6$, for similar reasons.

iderations likewise enter largely into the determination of molecular in compound gases and all compounds whose specific gravities can be he state of vapour, the molecule is assumed to be so constituted that ble of the specific gravity, that is to say, of the weight of a unit-volume This assumption cannot at present be said to rest on any physical found to be true in numerous cases in which the weight of the molecule spendently of it by purely chemical considerations; and hence it is ex- in which such verification cannot be obtained. Other physical con- h enter into the determination of molecular weights are specific heat, morphism, &c. (See ATOMIC WEIGHTS, i. 466–473; HEAT, iii. 30–40 MORPHISM, iii. 423–432.)

ecule, as applied to elements, must be understood in a somewhat rom that which it bears when applied to compounds. The smallest lementary body that can enter into a reaction is called, not a molecule, nd the molecule of an element is the smallest quantity, or group of exist in the free state. Many considerations lead us to suppose that in cases, this group consists of two elementary atoms, the molecule of xample, being HH. (See ATOMIC WEIGHTS, i. 466; and CHEMICAL,) There are also certain compound radicles, viz. the alcohol-radicles c., whose molecules in the free state are generally supposed to be the by which they enter into combination; *e.g.*, free methyl = $CH^3.CH^3$; tigations on the relations between these radicles and their hydrides ave thrown considerable doubt on the existence of these particular ules.

...UM. *Symbol*, Mo. *Atomic Weight*, 92.—A metal occurring in a sulphide (*molybdenite*), and as molybdate of lead (*wulfenite*). The was first distinguished from plumbago, which it much resembles, by 8; the metal was first prepared from the trioxide by Hjelm in 1782. plete investigations of the properties and combinations of this metal e by Berzelius (Pogg. Ann. iv. 153; vi. 361, 369; vii. 261); Struve (J. pr. Chem. xliv. 257; Jahresb. 1847–48, p. 408); Struve

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(J. pr. Chem. lxi. 449; Jahresb. 1854, p. 346); Blo
lxxvii. 88; lxxxii. 433; Jahresb. 1857, p. 191; 18
Schultze (Ann. Ch. Pharm. cxxvi. 49; Jahresb. 18
is derived from μολύβδαινα or *molybdæna*, applied
and other lead-compounds.*

Preparation.—Metallic molybdenum is prepare
oxides, or molybdate of ammonium, or acid molybda
in a crucible lined with charcoal. The reduction
performed on charcoal before the blowpipe with car
fused button of the metal, a very strong heat is requ
dry hydrogen gas over either of the oxides of mol
porcelain tube. (Berzelius.)

Properties.—Molybdenum reduced by hydrogen
acquires a metallic lustre by trituration, and con
Deville's blast-furnace, it is obtained as a white mas
than topaz, and of specific gravity 8·6. (Debray,
Molybdenum is unalterable in the air at ordin
heated it acquires, first a brownish-yellow, then a
(? the pulverulent metal) and burns to molybdic triox
dised by fusion with *nitre*, slowly by *hydrate of p*
boiling potash-lye. It dissolves in *nitric acid* with
hot strong *sulphuric acid* with evolution of sulphu
used in small quantity only, the metal is converted
proportion of sulphuric acid, the blue oxide is form
nitric acid the product is molybdic acid, which is a
state. Molybdenum is likewise oxidised and dissolved
of *nitric* with *sulphuric* or *hydrochloric acid*. It is
acid, slightly also by *phosphoric* and *boric acids*; not
acid. It reduces the oxides of *silver* and *mercury* v
in a stream of *aqueous vapour*, it is oxidised, with s

Combinations.—Molybdenum enters into combina
atomic, and sometimes also as a tri-atomic radicl
$Mo^{IV}O^2$, $Mo^{VI}O^3$, the chlorides, $Mo''Cl^2$ and $Mo^{IV}Cl$
the bromo-chloride, $Mo^{VI}Br^4Cl^2$, the oxychloride, M
the metallic series is not yet exactly ascertained, in
been determined, and those of its compounds whi
state at too high a temperature to allow of the det
(see page 968).

MOLYBDENUM, ALLOYS OF. Molybd
copper, silver, gold, and platinum, rendering them l
in the case of silver, whiter. *Molybdide of copp*
malleable if the molybdenum is not in excess. Wit
a black, brittle globule.—*Molybdide of iron* constitu
the hearths of copper-furnaces (p. 368). Equal p
yield a hard, brittle, shapeless lump, having a ligh
and appearing compact on the fractured surface.
num form a hard, brittle, bluish-grey alloy, havin
The alloy of 1 pt. *silver* and 2 pts. molybdenum is
Molybdide of Aluminium, AlI^2Mo, is obtained by
fluoric acid, evaporating to dryness, and fusing the
cryolite, 30 pts. of a mixture of the chlorides of so
proportions, and 15 pts. aluminium, at a strong re
regulus with soda-lye, there remains a crystall
film of metallic molybdenum, but assuming an i
nitric acid, and appearing under the microscope to co
a steel-blue tarnish when ignited in the air, and
hydrochloric acids. (Wöhler, Ann. Ch. Pharm. c

MOLYBDENUM, BROMIDES OF. (Blo
lxxxii. 433; Jahresb. 1859, p. 164; 1861, p. 239.)
over strongly heated molybdenum, an oxybromide i
sublimate of tribromide close to the heated part of
acquiring a yellowish-red colour and being at last co
between these two products there are also found iso
bromide, of a pure black colour.

* "Est et molybdæna, quam alio loco galenam vocavim
(Pliny.)

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omide or *Molybdous bromide*, $Mo''Br^2$, is produced, as just stated, by nation of its elements, also by heating the tribromide. It is a non-volatile, reddish-yellow body, which is not perceptibly attacked by hydrochloric, boiling nitromuriatic acid, but dissolves easily and completely when heated austic alkalis, forming a yellow solution containing molybdous oxybromide·

$$3MoBr^2 + 2KHO = 2KBr + H^2O + Mo^2Br^4O.$$

solutions of caustic alkalis decompose the bromide completely, with pre- a black hydrated oxide.

solution above mentioned, when exposed to the air, gradually deposits golden yellow crystals of a hydrated molybdous oxybromide,

^2O; but when neutralised with an oxygen-acid, it yields a dark yellow, granular precipitate of the same oxybromide with a smaller quantity of

$^4O.3H^2O$. The oxybromide dissolves with yellow colour in alkalis and in oxygen-acids, and from the acid solutions thus obtained, the bromine is not by silver salts.—The solution of the oxybromide in dilute aqueous alkalis *ydrobromic, hydrochloric*, or *hydriodic acid*, a yellow precipitate, insoluble

soluble in alkalis, and consisting of $Mo^2Br^4.3H^2O$, $Mo^2Br^4Cl^2.3H^2O$ or

^2O.—Blomstrand regards all these compounds as containing the diatomic *omolybdenum*, $MoBr^4$, *e.g.*, the oxybromide, $(MoBr^4)''O$, the chlorobromide, &c. (See page 1030.)

romide, $Mo''Br^3$, or *Molybdoso-molybdic bromide*, $MoBr^2.MoBr^4$, is above mentioned, by direct combination, or with greater facility by passing our over a heated mixture of molybdic oxide and charcoal. It is sometimes eparate crystals, but more frequently in blackish-green masses consisting apillary, interlaced needles. It is difficult to sublime, and at a bright red ed into the dibromide and free bromine. It is not even wetted by water, ked by boiling hydrochloric acid or by cold dilute nitric acid. Dilute pon it slowly, and at the boiling heat decompose it completely, with black molybdic hydrate.

abromide or *Molybdic bromide*, $Mo^{IV}Br^4$, formed also by direct com- 1028), is fusible and volatile, forming a brown-red vapour; it deliquesces a black liquid; and forms with water a yellow-brown solution, from which down molybdic hydrate of a rusty yellow colour. It is easily resolved by dibromide and free bromine, the temperatures at which it is formed and being very close together.

romide, $Mo^{VI}Br^6$, has not been obtained, but the corresponding *oxybro-* Br^2O^2, is produced by passing bromine-vapour over heated molybdic oxide, heating molybdic trioxide with boric, or phosphoric anhydride, and fusing d mass with bromide of potassium, *e.g.*:

$$MoO^3 + B^2O^3 + 2KBr = 2KBO^2 + MoBr^2O^2.$$

y sublimed, it forms indistinct crystalline scales; but by slow sublimation tained in more distinctly developed crystalline plates of yellow-red colour re, which deliquesce in contact with the air, and form a colourless solution

DENUM, CHLORIDES OF. Molybdenum forms three chlorides, the bromides. The tri-chloride and tetrachloride were first prepared by ho also obtained the dichloride in solution; these compounds have been xamined by Blomstrand, who has also obtained the anhydrous dichloride xychlorides.

de or *Molybdous Chloride*, $Mo''Cl^2$.—This compound is formed, the other chlorides, by passing chlorine-gas over heated molybdenum. It ared, though not in a state of purity, by exposing the trichloride to a at in an atmosphere of carbonic anhydride, or other gas which does not act y heating metallic molybdenum with calomel; also, though in very small passing chlorine-gas largely diluted with carbonic anhydride over mode- molybdenum; it is likewise formed in small quantity, together with the , by passing chlorine over a heated mixture of molybdic oxide and char- e temperature is very high. (Blomstrand.)

s chloride is obtained, in solution, by saturating hydrochloric acid with mo- rate. The dark-brown solution yields on evaporation a black mass which lmost entirely in water, but on evaporation in vacuo, gives off hydrochloric ter, and is converted into a black pulverulent oxychloride. (Berzelius.)

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The anhydrous dichloride is an amorphous po to greenish from the presence of impurities. dibromide, but dissolves easily and completely *hydriodic acids*. The alkaline solution when exp

oxychloride, $\ddot{M}o^3Cl^4O$, in combination with wa but generally as an amorphous gummy precipi

added to the same solution, throw down the hyd the form of light yellow flocks, which when rec water, dissolves easily in the stronger acids. (B

The hydrated oxychloride boiled with hydrobro yields solutions which deposit compounds of exac oxygen replaced by an equivalent quantity of *hydrobromic acid*, the chlorobromide, $Mo^3Cl^4Br^2$, yellow scales, insoluble in water, but soluble in a

concentrated at 100°, deposits short prismatic easily soluble in water and forming a solution unless it contains a large quantity of free acid

Similarly with *hydriodic acid*, the compound

crystalline substance, insoluble in water; also corresponding bromine-compound, but forms d

responding *chlorine-compounds*, $\ddot{M}o^3Cl^6.3H^2O$ an

$\ddot{M}oCl^2.2H^2O$), are obtained in like manner, the for the latter in light yellow slender needles or p forming a solution which soon becomes turbid. may be repeatedly evaporated to dryness, even in tible decomposition. The solid compounds he anhydride, first give off nothing but water; bu raised, a certain quantity of acid is given off, so t or less of the corresponding oxychloride, or even

$$Mo^3Cl^4Br^2 + H^2O = Mo^3Cl$$

and $Mo^3Cl^4Br^2 + 3H^2O = 3MoO$

The same decompositions take place, but to a g are heated in contact with moist air.

The haloïd molybdous compounds just described and ammonium, forming double salts having the $2NH^4Br$, $Mo^3Cl^4Br^2.2KBr$, &c., which crystallis acid solutions on cooling. These double salts yellow (the chlorine-salts), to deep yellowish-r various, usually prismatic form; are decomposed dissolving, while the molybdous compound (M combination with $3H^2O$; but dissolve without de acid. *Alcohol* dissolves some of them (Mo^3Cl decomposition, whereas from others (as Mo^3Cl^4B compound, and leaves the salt of the alkali-met solutions of these double salts, throws down only in them (*e.g.* from $Mo^3Cl^4Br^2.2KBr$, only the 4 at. $Mo^3Cl^4Cl^2.2KCl$, only 4 at. chlorine); moreover th by sulphydric acid, even after a day's contact (in slow decomposition), and they are not precipit From these reactions, and from the composition o that all these compounds contain the diatomic ra molybdous chloride is $(Mo^3Cl^4)''Cl^2$, the oxychl $(Mo^3Cl^4)Br^2$, &c.

Trichloride, $Mo'''Cl^3$, or *Molybdoso-moly* compound is obtained, though not in the pure stat chloride, $MoCl^4$, over heated molybdenum. Berze but does not appear to have analysed it, regarded Blomstrand's analysis, the compound thus obtaine The trichloride is more easily obtained by passing heated in a glass tube by a spirit-lamp; or better chloride mixed with carbonic anhydride, throu very strongly heated; the trichloride then collects

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lomstrand). It has a dark copper-red colour, and when heated to
of glass, in a vessel which does not allow access of air, it volatilises
usedly crystalline, dark brick-red sublimate (Berzelius). It is in-
but colours that liquid reddish when suspended in it; insoluble also
loric acid. When digested with *potash* it yields chloride of potassium
blackish-brown hydrated oxide of molybdenum. (Berzelius.)
de or *Molybdic chloride*, $Mo^{IV}Cl^4$. This compound, discovered by
uced when chlorine gas, free from air, is passed over gently heated
he metal then takes fire and burns on the surface for a few seconds;
on ceases and a dark red gas is formed, which condenses on the cold
el in dark coloured metallic-shining crystals having very much the
Blomstrand prepares it by the action of chlorine on strongly heated
e (the native sulphide). The crystals are very fusible (Berzelius),
t of fusion (Blomstrand), and sublime at a moderate heat. When
r, they fume at the first instant, and then deliquesce, the original black
uid passing through blue-green, greenish-yellow, and dark red into
kept in a vessel containing air, they absorb oxygen and yield a subli-
of an oxychloride.
ride when thrown into water, dissolves with such violence that the
and boils, as if a gas were given off, which however is not the case.
of the chloride drenched with a large quantity of water forms a solu-
turns green or blue from the oxidising action of the air; a stronger
permanent, and may be evaporated to dryness at a gentle heat without
ie tetrachloride then remaining as a black mass. Molybdic chloride
ined in solution by digesting the metal in hydrochloric acid, and add-
rom time to time till the liquid acquires a red-brown colour, or by
lic anhydride and pulverised molybdenum (or metallic copper) in
, till all the molybdic anhydride is dissolved and the liquid has become
solutions, ammonia forms a precipitate of molybdic hydrate.
bdic chloride is obtained, according to Berzelius, by mixing a solution
ide with ammonia, till the precipitate just begins to be permanent, and
ion to evaporate, the double salt then separating in small brown
compose in contact with air.
nolybdic chloride saturated with sal-ammoniac and left to evaporate
first deposits brown crystals of sal-ammoniac: and the mother-liquor
green octahedrons of the double salt $3MoCl^4.2NH^4Cl.6H^2O$, which
moist air to a black liquid becoming reddish-yellow when diluted,
ammonia a yellowish-red precipitate of molybdic hydrate. (Blom-

UM, CHLOROBROMIDES OF. This compound, $\ddot{Mo}^2Br^4Cl^2$, is

ction of hydrochloric acid on molybdous oxybromide, and $\ddot{Mo}^2Cl^4Br^2$
bromic acid on molybdous oxychloride. (Blomstrand, pp. 1029,

UM, DETECTION AND ESTIMATION OF. 1. *Blow-*
—Molybdic trioxide heated on charcoal in the outer flame is volati-
white crystalline sublimate on the charcoal; in the inner flame it may
without carbonate of sodium) to metallic molybdenum, which is sepa-
powder on levigating the charcoal. With *borax*, all the oxides of
, in the outer flame, a bead which is yellow while hot, and colourless
e inner flame, a dark brown bead, which is opaque if excess of molyb-
By long continued heating, the molybdic oxide may be separated
kes, floating in the clear yellow glass. With *microcosmic salt* in the
xides of molybdenum give a bead which is greenish while hot, and
ing; in the inner flame, a clear green bead from which molybdic oxide
ed by continued heat.
in Solution.—a. Solutions of molybdous salts obtained by dis-
s oxide in acids are opaque and almost black. They yield with *sul-*
rown-black precipitate, and with *sulphide of ammonium* a yellowish-
of sulphide of molybdenum easily soluble in sulphide of ammonium.
line carbonates produce a brownish-black precipitate of molybdous
in caustic alkalis, slightly soluble in the neutral carbonates, easily
rbonate of potassium or carbonate of ammonium. *Ferrocyanide* and
otassium form dark brown precipitates insoluble in excess. *Phosphate*
white precipitate.
molybdic salts have a reddish-brown colour. When heated in

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the air, they have a tendency to become blue by
zinc, they first blacken and then yield a blac
Their reactions with *alkalis*, *sulphydric acid*,
molybdous salts, excepting that the precipitates

γ. Molybdates are colourless unless they co
alkaline molybdates yield with *acids* a precipita
of the precipitant. They are coloured yellow by
sulphomolybdate of the alkali-metal R^2MoS^4,
precipitate of trisulphide of molybdenum. T
molybdic acid. They form white precipitates w
precipitates of various colours with salts of the
silver salts; yellow with ferric salts; and yellowi
nous chloride produces immediately a greenish-blu
acid, forming a green solution, which turns b
quantity of the tin-solution. *Mercurous nitrate* form
in nitric acid, blackened by ammonia. When
containing it, is added to the solution of molyb
excess of hydrochloric acid, the liquid turns yello
precipitate of molybdic acid combined with sma
ammmonia. This precipitate is soluble in ammo
phate. The reaction is therefore especially
quantities of phosphoric acid. The dibasic
produce the yellow precipitate. *Arsenic acid* giv

3. *Quantitative Estimation, and Separ*
the form of trioxide or molybdic anhydride (M
is to convert it into the di-oxide, MoO^2, by ignitio
oxide, which is not at all volatile, may then be w
in solution in ammonia or in other acids, the solu
dryness and the residue treated as above.

Molybdenum is separated from most metals by i
The filtered solution containing sulphomolybdate
excess of very dilute nitric acid, to precipitate the
lected on a weighed filter and its weight determi
it is ignited in an atmosphere of hydrogen, to
from the weight of which the amount of molybde

From arsenic, molybdenum may be separated
acid, and precipitating it by a magnesium-salt (i.
from molybdenum by the same process which se
tin (i. 369), the alkaline molybdates, like the ars
in water. For the separation of molybdenum fro

Molybdic acid is separated from the earths, by
of sodium, and digesting the fused mass in water,
and leaves the earth as carbonate.

From the fixed alkalis, molybdic acid may be
curous nitrate. The precipitate is thoroughly
mercurous nitrate, then dried and ignited at a m
gen, whereby it is reduced to molybdic oxide.

4. *Atomic Weight of Molybdenum.* B
51), endeavoured to determine the atomic we
of molybdate of lead, $PbMO^4$, obtained by preci
nitrate; in this way he obtained for molybdenum
regarded as only an approximation.

Svanberg and Struve (Ann. Ch. Pharm. lx
experiments, considered that the most accurate re
disulphide, MoS^2, in air. They found in ten expe
disulphide lost by roasting, from 9·929 to 10·3
taking the atomic weight of sulphur at 32, they ob
92·14; but the results of the individual experime
differed most widely from the rest) varied from 80
dence can be placed on the mean result.

Berlin, in 1850 (Ann. Ch. Pharm. lxxvi. 272),

$(NH^4)^2Mo^4O^{17}.3H^2O$ or $2NH^4$

and found the quantity of molybdic anhydride, Mo
experiments, only between 81·555 and 81·612: m
molybdenum the number 92, nearly the same as t

On the other hand, Dumas (Ann. Ch. Phys. [

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ide in a current of hydrogen, obtained in six experiments, values of
and 96·2: mean 95·7; he regards 96 as the true atomic weight of
ich is the same as that originally found by Berzelius.

UM, FLUORIDES OF. *a. Molybdous Fluoride.*—Molybdous
hydrofluoric acid, forming a purple-red liquid which dries up at a
varnish of the same colour; this residue when more strongly heated
colour, and partly insoluble in water.

dous fluoride is precipitated in pale red flocks on mixing a solution of
le with fluoride of potassium. It is dissolved by water containing a
d separates, during evaporation or on cooling, as a dark rose-coloured
comes lighter when dry. The *ammonium-salt* is exactly similar; the
re soluble.

luoride.—The solution of molybdic hydrate in aqueous hydrofluoric
the acid is in very large excess, in which case it is almost colourless.
oration, whereby it is soon rendered blue if the acid is not in excess,
rystalline residue (of molybdic fluoride?), which redissolves perfectly
a red solution; but if somewhat more strongly heated, loses acid,
d in water, leaves a residue of molybdic oxide. (Berzelius.)
molybdic fluoride are obtained by mixing the solution just described
s of the alkali-metals. They are rusty yellow powders, somewhat

of molybdenum yields with hydrofluoric acid a deep blue solution
ystallise. (Berzelius.)

Molybdic trioxide dissolves readily and abundantly in aqueous hy-
The colourless solution has a sour and disagreeable metallic taste, and
tion, a yellowish syrup which exhibits no signs of crystallisation;
h or bluish tint when heated, in consequence of minute organic par-
it; redissolves but imperfectly in water after evaporation to complete
es an insoluble compound of molybdic trioxide with a small proportion
id, or of molybdic trioxide with hexfluoride of molybdenum, which,
a certain extent in pure water, is precipitated from it by the first-
lution.

ations exist of hexfluoride of molybdenum with the more basic metal-
are not, however, known in the free state, but only in combination
bdic acid: *e. g.*, $K^2MoO^4.K^2MoF^6$. (Berzelius.)

UM GLANCE. Native sulphide of molybdenum (p. 1043).

UM, IODIDES OF. Molybdenum and iodine do not act on one
red heat. By dissolving molybdous hydrate in hydriodic acid, a so-
us iodide is obtained resembling that of molybdous chloride (p. 1029).
is obtained in solution by saturating hydriodic acid with molybdic
lution is red, and yields by evaporation in contact with the air, a
which is red by transmitted, brown by reflected light. It decomposes
rature, giving off hydriodic acid and leaving molybdic oxide. The
ontaneous evaporation redissolves in water. (Berzelius.)

UM, IODOBROMIDE and **IODOCHLORIDE OF.** $Mo^4Cl^4I^2$.—These compounds are obtained by the action of hydriodic
s oxybromide and oxychloride respectively (pp. 1029, 1030).

UM, NITRIDES and **AMIDES OF.** (Tuttle, Ann. Ch. Pharm.
b, Pogg. Ann. ci. 605; Jahresb. 1857, p. 194.)—These compounds,
been very exactly investigated, are obtained by passing ammonia-gas
rioxide, or the chlorides of molybdenum, at high temperatures.
g molybdic chloride in ammonia-gas till the resulting chloride of
olatilised, obtained a black sintered mass containing 82·8 per cent.
bably consisting of $2MoN.MoH^4N^2$.

so obtained compounds of similar constitution by the action of dry
nolybdic chloride. The action takes place even at ordinary tempera-
nded with sufficient evolution of heat to partially fuse the mass and
of ammonium. On subsequently applying a gentle heat, the product
nd soon solidifies to a black tumefied mass, exhibiting stellate groups
als on the colder parts; when completely freed from sal-ammoniac by
th water, and then dried in a vacuum over oil of vitriol, it exhibited a
ssible by the formula $Mo^3H^4N^{10}$ or $4MoN^2.MoN^2H^4$. This compound
oxygen gas, with formation of water, and gives off ammonia when
en gas, or fused with hydrate of potassium. A compound resembling
external appearance, but consisting of $8MoN.MoH^4N^2$, was obtained

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by heating molybdic chloride in ammonia-gas, th
redness. Molybdic chloride gradually heated to
yielded, but not always, the compound Mo^3N^2, whic
respects, but had a greyer colour; sometimes, howe
diate in composition between Mo^3N^2 and Mo^2N^2,
to whiteness in ammonia-gas, yield metallic moly

Molybdous chloride treated with ammonia-gas
with another, which, according to Uhrlaub, is ana
platinum-bases.

Nitrides and amides of molybdenum are likewis
gas on molybdic anhydride. The reaction appears
MoN^2, MoH^4N^2, Mo^2N^2, and Mo^3N^2, being obtain
to the temperature, and often uniting together t
composition.

MOLYBDENUM, OXIDES OF. Molyb
following composition:

Protoxide or Molybdous oxide	.
Dioxide or Molybdic oxide	. .
Trioxide or Molybdic anhydride	.

The first two are basylous and form salts with
with some of the stronger acids, but it is decide
readily with the more basylous metallic oxides, an
called Molybdates. There is also an oxide (
diate between the di- and tri-oxide, which may be

Protoxide or **Molybdous oxide,** MoO. Th
di- or tri-oxide, in presence of one of the strong
metals which are capable of decomposing water.
concentrated solution of an alkaline molybdate m
acid sufficient to redissolve the molybdic acid whic
becomes first blue, then reddish-brown, and fina
zinc and molybdous chloride. To separate the m
is then added to the liquid in quantity just suffic
as black molybdous hydrate, while the zinc re
however, carries down with it a certain quantity
freed by washing with ammonia; but it is difficul
hydrate quite free from zinc. A better mode of pr
solution of the molybdate with an amalgam of po
quantity of potassium, and precipitate the resulting
ammonia as before.

Anhydrous molybdous oxide may be obtaine
of vitriol in a vacuum, and then igniting it out
by digesting the fused or sublimed trioxide for a
acid and zinc.

Anhydrous molybdous oxide is perfectly black
pared by the last method exhibits a dark brass-
direct rays of the sun; it also exhibits the crystall
it has been prepared, and oxidises in the air more
by igniting the hydrate. The anhydrous oxide, w
a vivid but momentary light, indicating its passag
insoluble in acids, but the hydrate dissolves slowly, f
solutions of which are black or purple, and nearly
in which case they are transparent, and have a gr
astringent but not metallic; when exposed to the ai
the molybdic salts.

Dioxide or Molybdic Oxide. MoO^2.—Thi
molybdic hydrate in a vacuum (Berzelius).—2. I
of hydrogen to a heat not greater than that of an
It is also said to be produced by igniting molybd
or by igniting a mixture of potassic or sodic
dissolving out the soluble chloride with water; bu
to be contaminated with nitrate of molybdenum.

Molybdic oxide is red-brown. It is not att
hydrochloric acid, or by hydrochloric acid gas a
solution of acid tartrate of potassium takes up o
digestion, and the residue left after decanting t
quantities of sulphuric acid or solution of cream of

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gnition in the air, or by treatment with nitric acid. Caustic potash-
er oxidises nor dissolves it.

hydrate is obtained by precipitating a solution of molybdic chloride or
ic salt with ammonia, which must be added in excess, as otherwise a
sult will be formed, especially with the chloride. The hydrate itself is
t soluble in pure water, so that, in very dilute solutions, ammonia does not
ipitate until sal-ammoniac is added. For the same reason, the washing
arried too far, and is best finished with water containing alcohol. The
ate may be pressed between paper and dried in a vacuum. It has a
olour, just like that of ferric hydrate precipitated by ammonia. When
e moist state to the air on filtering paper, it acquires a darker colour and
ce, and begins to deliquesce, passing into a higher and much more soluble
solves, as already observed, in a large quantity of water, forming a dark
which gelatinises when kept for three or four weeks in a closed vessel,
s, a property likewise retained by the hydrate precipitated from it by
, and has a somewhat astringent taste, with metallic after-taste. This
n left to evaporate spontaneously, first gelatinises and then dries up to a
nearly black mass, green and blue on the edges, which is no longer
ter. The hydrate is insoluble in caustic potash, but dissolves in aqueous
ate of potassium, and more easily in the acid carbonate, from which solu-
ially precipitated on boiling. It dissolves also in carbonate of ammo-
completely precipitated therefrom by boiling; the precipitate is denser
ter yellow colour than that obtained with caustic ammonia, but dissolves,
, when washed with water. A solution of molybdic oxide in an alkaline
onverted by atmospheric oxidation into a molybdate of the alkali-metal.
ydrate dissolves in *acids*, forming the molybdic salts. These salts may
ned by digesting an excess of metallic molybdenum with the acid in
e dissolved, and adding nitric acid drop by drop till the other acid is
h molybdic oxide; or by digesting an excess of molybdenum with
hydride, and the acid which is required to dissolve the resulting
le—hydrochloric acid, for example—till the blue colour first produced
ddish-brown; or lastly, by digesting molybdic anhydride with copper and
h in that case dissolves cupric and molybdic oxides together. The
s, in the anhydrous state, are almost black, but when hydrated they are
d reddish-brown solutions in water. They have a rough, somewhat
d subsequently metallic taste. Their solutions when heated in contact
have a tendency to become blue by oxidation. [For their behaviour with
p. 1039.]

s intermediate between the di- and tri-oxides will be described as
ybdates (p. 1039).

Molybdic Anhydride, Anhydrous Molybdic acid, MoO^3.—This oxide
as molybdic ochre or molybdin, forming an earthy coating on the
de, sometimes also independently; at Altenberg in Saxony it occurs in
ns of 136° 48′ (Breithaupt, Jahresb. 1858, p. 683). It may be formed
exposing molybdenum or its lower oxides, or molybdic sulphide, to long-
t in contact with the air, by fusing the same substances with nitre, or by
etal or its oxides in an atmosphere of aqueous vapour, or with hydrate of

a. From *Molybdic Sulphide.*—The precipitated sulphide, or the native
pulverised, is roasted, with continued stirring, in an open crucible placed
position, so that the air may easily play upon its surface. The native
ever, generally contains alumina, oxide of copper, and phosphoric acid,
of which from the product is very troublesome. Hence it is better to
ral in lumps in an open glass tube, through which a stream of air is
aspirator; the trioxide then sublimes in crystals in a state of perfect
hler, Ann. Ch. Pharm. c. 376.)

tive *Molybdate of lead.*—The mineral finely pounded and freed from car-
e, iron, and calcium, by digestion in dilute hydrochloric acid, and thoroughly
cantation, is heated with 1½ pt. strong sulphuric acid, with constant stir-
ulphuric acid begins to evaporate. It is then allowed to cool, a considerable
ater is added, and the insoluble sulphate of lead is filtered off. The
ed with nitric acid and evaporated, with constant stirring, in a porcelain
acid begins to evaporate; the molybdic anhydride then separates as a
, which may be freed from phosphoric acid by washing with water,
last with a few drops of nitric acid.—Or the mineral, after treatment with
hloric acid, may be evaporated to dryness with strong hydrochloric acid,
ue (containing oxychloride of lead and molybdic anhydride) exhausted

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with ammonia; the ammoniacal solution crystal
nitric acid; and the residue treated with water.
its own weight of calcined cream of tartar; the fu
the aqueous solution exaporated to dryness, after
nitrate of potassium is dissolved out of the residue
than remains behind.

Properties.—Trioxide of molybdenum, as usu
porous mass, which when thrown into water, sepa
silky lustre and glistening in sunshine. Specific gr
to a dark yellow liquid, which on cooling forms a
crystalline scales. By slow cooling of the melte
belonging to the trimetric system and exhibitin
(referred to the prism ∞P, observed by Breithaup
axes to principal axis = 1 : 0·3872 : 0·4792 (No
In close vessels it bears a strong red heat without
a current of air, it sublimes at its melting point ir

Decompositions.—1. Molybdic trioxide is reduce
with *potassium* or *sodium* (with vivid incandes
strongly heated in a stream of *hydrogen*.—2. To mol
chloric acid and *amalgam of potassium*, or *zinc*, o
water.—3. To molybdic oxide, by ignition in
digestion with *hydrochloric acid* and *molybdenum*
(Ann. Ch. Pharm. cx. 257), by subjecting it in t
electric current; the molybdic oxide thus separat
forming the compound $MoO^2.2MoO^3$ or Mo^3O^8, v
and gradually forms a conducting communication
of blue oxide, by a small quantity of *sulphydric aci*
to heat, with separation of sulphur; by *sulphuro*
acid; by aqueous *hydriodic acid*, with separation
liquid which at first is green, but afterwards blue
disengagement of chlorine; by *nitric oxide* in p
nitrous acid (Kastner, Kastn. Arch. xxvi. 465); b
stannic chloride; also by digestion with water and *m*
molybdenum, by *sulphydric acid* in excess, in pres
Molybdic trioxide is not affected by fusion with n

Combinations. 1. With Water.—Molybdic t
It dissolves, according to Bucholz, in 500 parts o
quantity at a higher temperature: according to H
water. The solution has a faint metallic taste
precipitate with ferrocyanide of potassium, but
added. Graham (Chem. Soc. J. xvii. 326), by di
mixed with a large excess of hydrochloric acid, l
acid (containing about 60 per cent. of the quant
having a yellow colour, astringent to the taste,
decomposing carbonates with effervescence. Eva
molybdic trioxide in scales like gum or gelatin,
not appear possible to obtain molybdic acid in

2. With Acids. The affinity of molybdic acid
ignition, it is but slightly soluble in a boiling
before ignition, however, it dissolves in some of t
phoric, *sulphuric*, *nitric*, and *hydrochloric acid*
called permolybdic salts. The solutions th
sometimes yellow or brownish. By metallic *zinc* o
green, and lastly black, molybdous oxide being p
they become dark red. *Stannous chloride* produc
dissolves in hydrochloric acid, forming a green so
quantities, colours them blue; in larger quan
precipitate (a mixture of disulphide of molyb
Berzelius). *Sulphide of ammonium* behaves in
(Bucholz, Berzelius). *Ferrocyanide of potass*
precipitate, soluble in excess of the reagent, a
Ferricyanide of potassium gives a somewhat lig
likewise soluble in ammonia (H. Rose). *Tinc*
precipitate. (Smithson.)

Permolybdic Borate. Molybdic trioxide dissolv
the filtered solution yields by evaporation colourl
into a yellow powder and boric acid. (Berzeliu

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itrate. The solution of molybdic trioxide in nitric acid is reddish-
ply acid and subsequently bitter, metallic, astringent taste, and gives
nen evaporated.

hosphate or *Phosphomolybdic Acid.* Molybdic trioxide digested while
a small quantity of aqueous phosphoric acid, yields a lemon-yellow
water (Berzelius). With a larger proportion of phosphoric acid,
lissolves on the application of heat, forming a colourless liquid, which
ation, a tenacious, uncrystallisable, transparent mass, having a very
very soluble in water and in alcohol. The alcoholic solution is yellow,
n evaporation, and leaves a brown, opaque residue, which redissolves
g a blue solution. (Berzelius; see also Svanberg and Struve,
. lxviii. 209, 293.)

ecipitate formed on adding molybdate of ammonium to the solution of
nate (p. 1032) appears to vary in composition according to the circum-
rmation; at all events the formulæ (all very complicated) assigned to
emists do not agree with one another (see Nutzinger, Jahresb. 1855,
ohn, *ibid.* 1856. p. 375.—Eggertz, *ibid.* 1860, p. 620).—[For the
g phosphomolybdic as a test for the alkaloïds, see i. 127.]

ulphate. By boiling dilute sulphuric acid with an excess of molybdic
l, milky liquid is obtained, which gelatinises on cooling, and deposits
s of a basic compound, sparingly soluble in water but not in alcohol,
colours it green. (Berzelius.)

molybdic trioxide (not in excess) in dilute sulphuric acid has a light
nd dries up to a lemon-yellow crystalline mass, which deliquesces in
ly partially soluble in water (Berzelius). According to Ander-
esb. xxiii. 161), the solution of molybdic acid in sulphuric acid does
s on evaporation; but when molybdate of barium is decomposed by
sulphuric acid, and the clear solution evaporated over oil of vitriol,
ned.

artrate. The solution of molybdic trioxide in aqueous tartaric acid,
ation a blue non-crystalline mass, perfectly soluble in water and in
ng solution of acid tartrate of potassium easily dissolves molybdic tri-
ignition. The solution dries up to a gummy mass of *potassio-per-*
. (Berzelius.)

es, forming the Molybdates. Molybdic trioxide exhibits with most
he characters of an anhydrous acid, or anhydride, forming neutral
ontaining $R^2O.MoO^3$ or R^2MoO^4; acid and double molybdates,
epresented by the general formula $R^{2n}Mo^nO^{4n}$, the molecule R^{2n} being
or more metals, including hydrogen; and anhydro-molybdates,
he general formula $R^{2n}Mo^nO^{4n}.mMoO^3$, the letters m and n represent-
ers. The neutral molybdates of the alkali-metals are easily soluble
e obtained by digesting molybdic anhydride with the aqueous alkalis
nates. They are decomposed by the stronger acids, with precipitation
oluble acid salt, or of molybdic anhydride. Their behaviour with other
n already described (p. 1032). The molybdates of the other metals are
e obtained by precipitation. They are colourless unless they contain

of Aluminium. White precipitate, insoluble in water.

of Ammonium. The *neutral salt*, $(NH^4)^2MoO^4$, is obtained by
ic anhydride in excess with strong aqueous ammonia in a closed vessel,
solution with alcohol, and drying over quicklime.

These are obtained by evaporating a solution of molybdic anhydride
monia. If the evaporation takes place quickly, a crystalline powder is
ich, according to Svanberg and Struve, is an anhydro-molybdate,
or $(NH^4)^2MoO^4.MoO^3$. It is probable, however, that the salt thus
s 1 at. water, $[(NH^4)^2O.2MoO^3.H^2O]$, in which case it may be regarded

ydric molybdate, $\left.\begin{matrix}NH^4\\H\end{matrix}\right\}MoO^4$. A salt having this composition is in
y v. Rath (Pogg. Ann. cx. 18) as crystallising in monoclinic prisms,
$\infty P\infty$] . $\infty P\infty$. — P . + 2P, and having the ratio of the axes
6297 : 1 : 0·2936; the angle of the inclined axes = 91° 12′; and
le parallel to [$\infty P\infty$].

onio-hexhydric-molybdate, $\left.\begin{matrix}(NH^4)^4\\H^6\end{matrix}\right\}Mo^5O^{20}$, separates from a solution
ydride in ammonia, when concentrated to the crystallising point or left
e air, in large transparent six-sided prisms. (Svanberg and Struve.)
ion of this salt is boiled with *aluminic, chromic, ferric* or *manganic*

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hydrate, and then evaporated to t
the composition of which may be

$3[(NH^1)^2O.2MoO^3] + \dddot{Al}^2O^3.6MoO^3$

crystallises in small, white, shining
responding potassium-salt (which
give off $3\frac{1}{4}$ at. water when exposed
crystallisation) between 100° and 1
(which are basic) at a higher temp
yellowish residue of alumina and
ginal crystals.

The *ammonio-chromic salt* crysta
off 5 at. water at 100° and 2 at. mo
ture of chromic oxide and molybdic
white crystals of the same form, but

The *ammonio-manganic salt*, $5[$

$\left.\begin{matrix}(NH^4)^5\\(Mn)'''\\H^8\end{matrix}\right\}Mo^8O^{32}.2H^2O$, is isomorpho

dissolves in 101·7 pts. water at 17°;
of its total quantity of water at 10

Molybdates of Barium. Th
sparingly soluble crystalline powd
molybdic acid in excess of ammoni

Schultze by fusing together 2
and 2 pts. chloride of sodium, obta
with 4 pts. sodic chloride it was ob

The salts $Ba''H^4Mo^8O^{12}.H^2O$ and
the corresponding potassium- and
decomposing monobarytic molybdat
containing $Ba''MoO^4.8MoO^3.4H^2O$,
insoluble in water. (Svanberg a

Molybdate of Cadmium, Cd
melting together 2 pts. molybdate
common salt. (Schultze.)

Molybdate of Calcium, Ca''
date of sodium, 6 pts. chloride of
developed quadratic pyramids. (S

Cerous Molybdate is obtained
but soluble in several acids. (Ber

Molybdates of Chromium.
obtained, as above described, by dis
ammonium and potassium.

Molybdate of Cobalt is obtaine
molybdate of sodium with 2 pts. chlo

Cupric Molybdate. Yellowish
posed by acids and by alkalis (Berz
boiling solution of cupric sulphate t
sisting of a basic cupric molybdate,
By adding molybdate of ammonium
an *ammonio-cupric salt* is formed
$[Cu''(NH^4)^2H^8]Mo^5O^{20}.6H^2O$. It is
4 at. water at 100° and 4 at. more a

Molybdates of Iron. Monof
brown monoclinic prisms by fusing 1
and 2 pts. common salt (Schultze)
sic molybdate reduces the molybdic a
be passed through the solution at th
when dried in the air, forms a light
(Struve). A solution of acid moly
of ferric chloride immediately produc
dried contains $Fe^2O^3.4MoO^3.7H^2O$.

A mineral from Nevada city in C
887) as a ferric molybdate, is, accord

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sition, and appears to be merely a mixture of molybdic ochre and

and *Potassio-ferric molybdates* are obtained in the manner already
7).

f Lead. $PbO.MoO^3 = Pb''MoO^4$. This salt occurs native as *Wulfad ore* (*Gelbbleierz*) in modified square tables and octahedrons belonging ic system, the most frequent forms being P and P . oP. Length of 1·574. Angle P : P in the terminal edges = 99° 40′; in the lateral Cleavage indistinct parallel to P. It occurs also granularly massive, ly coherent. Hardness = 2·75 to 3. Specific gravity = 6·3 to 6·9. adamantine. Colour wax-yellow passing into orange-yellow, also reen, yellowish-grey, greyish-white and brown. Streak white. Subbtranslucent. Fracture subconchoïdal. Brittle. When heated, it gly, and assumes a darker colour, disappearing however on cooling, ow mass. When fused on charcoal before the blowpipe, it sinks into ng globules of lead, the charcoal at the same time becoming impregdenum and molybdide of lead. It dissolves easily in *borax* and in xhibiting the reactions of molybdenum already mentioned (p. 1032). *nitric acid*, with separation of yellowish-white permolybdic nitrate, g *hydrochloric acid* dissolves it, forming a green solution, together ead, which separates more completely on addition of alcohol. It distic *potash*.

ad occurs, with other lead ores, in veins of limestone, at Schwarzend Windish-Kappel, in Carinthia; it is also found at Retzbanya, in Moldawa in the Bannat, where the crystals are red, and bear co nce to chromate of lead; in small quantities also at the Southampton chusetts, and in fine reddish orange crystals, containing a trace of Wheatley's lead mine near Phœnixville, Pennsylvania. The specimens localities are nearly pure, the proportion of molybdic anhydride varying from 37·65 to 40·5 per cent., and that of lead-oxide from ont., while the formula $PbO.MoO^3$ requires 38·5 per cent. MoO^3 and Bleiberg mineral contains a small quantity of vanadium.

ad is formed artificially by precipitating nitrate of lead with neutral monium; also, according to Schulze, by fusing 2 pts. molybdate of s. chloride of lead and 4 pts. common salt. As thus prepared, it ite when pure, yellow if they contain a little phosphoric acid. Mixproportions, of molybdate of sodium, chromate of potassium, chloride on salt, yield crystallised salts, which, when they contain not more chromate of lead, are quadratic like those of pure molybdate of lead, ed colour; with from 42 to 90 per cent. chromate of lead, they are llow.

lead from Pampluna, in South America, was found by Boussing-Phys. [3] xlv. 325) to contain 73·8 per cent. PbO, 10·0 MoO^3, 2·9 P^2O^5, 1·2 Cr^2O^3, 1·7 FeO^3, 2·2 Al^2O^3 and 3·7 quartz (= 98·1); he sic salt, $3PbO.MoO^3$ or $Pb''MoO^4.2Pb''O$.

f Magnesium, $Mg''MoO^4.5H^2O$, is obtained in distinct crystals ic acid and *magnesia alba* with water, and evaporating the filtrate; ater at 100°. (Struve.)

Manganese is obtained as a heavy, white, crystalline powder, $O^4.H^2O$, by treating carbonate of manganese with trimolybdate of m; it gives off its water above 100°, dissolves sparingly in boiling oiled for some time with the acid molybdate of potassium or sodium, (Struve). Schultze, by fusing 1 pt. molybdate of sodium with chloride, and 2 pts. common salt, obtained the anhydrous salt ge dingy yellow crystals having the aspect of bitter spar, and apmicroscope as small monoclinic [?] tablets. Together with this salt med large red-brown laminæ of indeterminate form.

potassio-manganic molybdates are prepared by boiling the acid molybn and potassium with manganic hydrate (pp. 1037, 1040).

of Mercury. On adding mercurous nitrate to a solution of tassium, a yellowish-white flocculent precipitate is formed, which, if ted on a filter, and washed till the wash-water leaves no residue d ignition, consists of *mercurous dimolybdate* or *anhydro-molybdate*, $Hg.MoO^4.MoO^3$. It is yellowish-white and non-crystalline, but is nged washing, or more quickly by boiling in the mother-liquor, into

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golden-yellow needle-shaped cr
(Struve.)

Molybdates of Molybden
mediate in composition between
containing molybdenum as their
mixed with a solution of molyb
composition of a molybdic m
thus formed is, however, a hydr
same blue hydrate is formed by t
dic salts (pp. 1035, 1036). It
more in water, slightly also in a
remains unaltered at ordinary t
when evaporated by heat. A co
a dilute solution on warming, in

Another molybdic molybdat
$MoO^2.2MoO^3 = Mo^3O^8$, is form
molybdic chloride is precipitate
with pulverised molybdenum, or
trioxide are digested with a larg
liquid then changing from blue
niac throws down the compound
washed with water. From the
first the compound $MoO^2.4MoO$

Molybdate of Nickel for
fusing molybdate of sodium wi
clinic prisms, together with lem

Molybdates of Potassi
K^2MoO^4, is obtained by agita
separates as an oily mass, whic
in four-sided prisms containing
lution of molybdate of ammoni
rating to a syrup.

β. When a solution of molyb
nitric or hydrochloric acid, till
a while, yields crystals of a salt
and this salt is decomposed by
and the trimolybdate, which is

$$2(4K^2O.9MoO^3)$$

The *trimolybdate* dissolves ea
precipitate when the solution is
beautiful silky needles containi

Nitric acid added in excess to
throws down a white precipita
$K^2O.5MoO^3$, both anhydrous.

Potassio-aluminic Molybdate,

sition to the ammonio-alumini
either by prolonged boiling of
hydrate; or by precipitating a s
nesium, for example, and boiling
sulphate, and molybdate (mixed
trimolybdate, and evaporating t
groups of small white square ta
air at ordinary temperatures; g
heated, and solidifies on cooling
water and even in acids. (Str

The *potassio-chromic salt* of s
soluble in 38·51 per cent. water
100°, and behaving at higher te

The *potassio-ferric salt* form
ceding salts; difficult to obtain

The *potassio-manganic salt,*

is prepared, either by boiling

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ing chlorine through a hot solution of potassic trimolybdate, and g small quantities of manganous sulphate, as long as the solution is d darker in colour. The filtered liquid yields the double salt, after ntration, in shining orange-coloured rhombohedrons, having the angle al edges = 107° 45'. It dissolves in 384·3 pts. water at 17°, more water, by which however it is partially decomposed. It gives off 9 at 2 at. more at 160°, acquiring at the same time a darker colour; melts perature, and solidifies on cooling into a brownish-red crystalline mass. silver, it forms a precipitate containing molybdic acid, manganic oxide, , which decomposes during washing. (Struve.)

s of Silver.—*α. Neutral argentic molybdate*, Ag^2MoO^4, is obtained by e neutral potassium-salt with nitrate of silver as a yellowish-white, floc- te, which darkens on exposure to light, dissolves sparingly in water, nitric acid.—*β.* Trimolybdate of potassium forms with nitrate of silver te flocculent precipitate, of somewhat variable composition, but agreeing rmula $2Ag^2MoO^4.3MoO^3$. (Svanberg and Struve.)

olybdate, $Ag^4O.2MoO^3 = Ag^4MoO^7$, is produced by the action of hydro- nary temperatures on the neutral argentic salt; or better, by passing hrough a tube having a narrow aperture, into a saturated solution of t in moderately strong aqueous ammonia; the reduction then also takes y temperatures, but much more quickly at 90° (at higher temperatures ver may be reduced to the metallic state). By the first method it is amorphous mass; by the second, as a black, shining, crystalline powder, gular octahedrons. It is dissolved by nitric acid, with evolution of d decomposed by potash (not by dilute ammonia) with separation of oxide. (Wöhler, Ann. Ch. Pharm. cxiv. 119.)

s of Sodium.—The *neutral* or *disodic molybdate*, $Na^2MoO^4.H^2O$ ed the *monomolybdate*), is obtained by fusing molybdic anhydride with uantity of crystallised carbonate of sodium. It is easily soluble in water, in small octahedrons, which melt and give off their water at a moderate *ydric* molybdate, $NaHMoO^4$ (or *dimolybdate*, $Na^2O.2MoO^3.H^2O$), ob- ilar manner, crystallises in needles, and dissolves sparingly in cold, ing water. The *disodio-tetrahydric molybdate*, $Na^2H^4Mo^5O^{17}.5H^2O$ (or $Na^2O.3MoO^3.7H^2O$), is obtained, by adding nitric acid to a solution of n carbonate of sodium, as a bulky white precipitate, more soluble than ing potassium-salt. Nitric acid, added in excess to a solution of odium, throws down nothing but molybdic anhydride. (Svanberg and

e of sodium boiled with alumina, chromic oxide, &c., forms double salts e potassium-salts above described.

of Strontium is obtained in well-developed square pyramids by 1 pt. molybdate of sodium, 2 pts. chloride of strontium and 2 pts. (Schultze.)

of Zinc, $Zn^{"}MoO^4$, is obtained by fusing 2 pts. molybdate of sodium oride of zinc and 6 pts. common salt, in white needles, with a tinge of ng under the microscope as square prisms, also exhibiting the combi- ; fusible without decomposition before the blowpipe. (Schultze.)

ENUM, OXYBROMIDES OF. *Molybdous Oxybromide*, $M\ddot{o}^{v}Br^4O$, heating molybdous bromide with dilute solutions of caustic alkalis; with hydrochloric, hydriodic and hydrobromic acid, it yields molybdous &c. (Blomstrand, see p. 1029.)

Oxybromide, $Mo^{vi}Br^2O^2$, is produced by passing bromine vapour over xide, or by fusing molybdic trioxide with boric or phosphoric anhydride, e pulverised mass with bromide of potassium:

$$MoO^3 + B^2O^3 + 2KBr = 2KBO^2 + MoBr^2O^2.$$

sublimed, it forms indistinct crystalline scales; by slow sublimation, eloped crystalline plates. It has a yellowish-red colour and fatty lustre, the air, and forms a colourless solution with water. (Blomstrand.)

ENUM, OXYCHLORIDES OF. *Molybdous Oxychloride*,

roduced in the same manner as the corresponding oxybromide, and ilar manner with hydrochloric acid, &c. (Blomstrand, p. 1039.)

lic Oxychlorides. *α.* $Mo^{vi}Cl^2O^2$ or $MoCl^6.2MoO^3$.—Discovered by

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Berzelius, first correctly analysed by H. Rose (I
in the amorphous state, when any other chlorine-c
in contact with the air, and when the same compou
at ordinary temperatures (Blomstrand, Jahresb
line state it is obtained by the following proces
the heated dioxide (Berzelius).—2. By pouring
of molybdic trioxide and potassic sulphate, evaporat
completely as possible, then adding chloride of sodi
the oxychloride sublimes; but this process does n
first (H. Rose).—3. By repeated sublimation of
strand).—4. By subliming a mixture of this bro
modification of α (Blomstrand). It forms yellowi
(Berzelius); thin, translucent, nearly square pl
obtained by the fourth method, thicker crystals o
translucent (Blomstrand). Tastes sharp and as
volatilises, without fusing, at a heat below redn
molybdic and hydrochloric acids, both of which r
in alcohol.

A hydrate of the preceding compound, $MoCl^2O^2$
as a *hydrochlorate of molybdic trioxide*, $MoO^3.2HCl$,
acid gas over the trioxide heated to 150°—200°, a
substance, which is resolved by heat into hydrocl
denum, but may be volatilised without decomposit
dissolves easily in water, but the solution whe
molybdic trioxide (Debray, Ann. Ch. Pharm. cviii.
nitrate, &c., described at p. 1037, are perhaps analog
just mentioned, but they have not been analysed.

β. $Mo^{vi}Cl^4O$ or $2MoCl^6.MoO^3$?. This is a
obtained by passing chlorine over an intimate mixtu
(or even imperfectly reduced molybdenum still
common spirit-lamp. The bulky amorphous oxyc
removed, and the sublimate which forms when the
blood-red colour is to be collected. It is indistinctl
if formed at a somewhat stronger heat, in light
melts and volatilises below 100°, forming a dark red
by water, yielding hydrochloric acid and blue ox
from the results of analysis, Blomstrand regards it a
$MoO^2.2MoO^3$, but observes that the analytical numb
required by the simpler formula above given.

γ. $Mo^4Cl^{10}O^5 = (MoCl^4.MoCl^6).(MoO^2.MoO^3)$.
stance, produced by the action of chlorine on a mix
molybdenum (formed from the trioxide by the prolo
heat, or by the reducing action of zinc in the v
product is collected apart and purified by fractiona
hydrogen. When very slowly sublimed, it forms la
(Blomstrand.)

δ. $Mo^2Cl^6O^3 = MoCl^6.MoO^3$. Produced, thou
quantity, by the action of chlorine at a moderate he
and charcoal, accompanying the green oxychloride β,
part of the process. It may be freed from the latter,
may be present, by its inferior volatility. It forms
dark violet colour by reflected, ruby-red by trans
difficulty, but without previous fusion. Water fi
temperature, and then throws down a white precipit
water.

MOLYBDENUM, PHOSPHIDE OF. Mo
oxide of molybdenum containing phosphoric acid,
containing lime, is exposed for an hour in a char
strong coke fire, whereby a grey blistered mass is fo
shining crystals of phosphide of molybdenum, mixe
its cavities lined with the same crystals.

Phosphide of molybdenum forms a powder of spe
conduct electricity. It is very difficult to fuse; oxi
burning, but with incandescence on melting *nitre*.
into phosphoric and molybdic acids, and dissolved.
gas, it is converted, without visible combustion,

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chloride of phosphorus. In contact with *zinc* it eliminates hydrogen from *hydrochloric acid*, and on addition of a *copper-salt*, reduces copper on its surface. (Wöhler and Rautenberg, Ann. Ch. Pharm. cix. 374.)

MOLYBDENUM, SULPHIDES OF. Molybdenum unites with sulphur in three proportions, forming the compounds MoS^2, MoS^3, and MoS^4. The last two are sulphur-acids. Our knowledge of these sulphides and their salts is almost wholly due to the researches of Berzelius.

Disulphide or Molybdic Sulphide. MoS^2.—This compound occurs native as *Molybdenite* (*Molybdänglanz*, *Wasserblei*), generally in crystallo-laminar masses, more rarely in tabular crystals, ∞P . oP, belonging to the hexagonal system, cleavable parallel to oP. Hardness = 1 to 1·5; easily impressed by the nail. Specific gravity = 4·44 to 4·8. The mineral has a strong metallic lustre and pure lead-grey colour; streak similar, but slightly inclined to green; it forms a grey trace on paper, and a greenish trace on porcelain. It is opaque, sectile, and almost malleable; laminæ highly flexible and elastic.

Molybdenite is of frequent occurrence in primitive rocks, being sometimes found in metalliferous veins, especially of magnetic iron ore and tin ores. It is found in Cornwall, at Caldbeck Fell in Cumberland, in Saxony, Bohemia, Sweden, Norway, and Greenland, and at numerous localities in the United States. It occurs nearly pure, but according to Svanberg and Struve, generally contains a small quantity of phosphoric acid (or phosphorus), a fact which must be borne in mind when the mineral is used for the preparation of molybdate of ammonium.

Disulphide of molybdenum is produced artificially by heating either of the higher sulphides, also by igniting the trioxide with sulphur. The artificial sulphide is a black shining powder.

The disulphide heated in closed vessels, sustains a high temperature without fusing or undergoing any change, and according to H. Rose, is not decomposed by ignition in dry hydrogen gas. When heated in the air, it is converted into molybdic anhydride, with evolution of sulphurous anhydride. Before the blowpipe on *charcoal* it gives off sulphurous anhydride, covering the charcoal with a yellowish-white incrustation; but it burns with great difficulty, and the combustion is but imperfect. On *platinum wire* it colours the outer blowpipe flame green. It colours a bead of *borax* mixed with *nitre*, dark brown in the inner flame, and light brown in the outer.

It decomposes *vapour of water* at a red heat slightly, but at a higher temperature with greater facility. It detonates with *nitre*, forming a molybdate of potassium; dissolves readily in warm *nitromuriatic acid*, producing molybdic and sulphuric acids, is easily oxidised by *nitric acid*; dissolves in boiling oil of vitriol with evolution of anhydride, and forms a blue solution.

Trisulphide. *Sulphomolybdic acid.* MoS^3.—This compound, the analogue of the trioxide, is formed by decomposing that compound with sulphydric acid, viz. (1) by passing the gas into a concentrated solution of an alkaline molybdate and precipitating with an acid; or (2) by adding sulphide of ammonium to the solution and then hydrochloric acid, both in excess. The whole of the molybdenum is then precipitated as trisulphide, which settles down quickly, and must be rapidly washed on a filter with water containing sulphydric and hydrochloric acids, to prevent oxidation. As thus obtained it is a black-brown powder which makes a dark brown streak on porcelain. When heated it gives off sulphur, and is converted into the disulphide. It dissolves, but not readily, in caustic alkalis, more easily at the boiling heat, undergoing partial decomposition at the same time. It is most easily dissolved by *alkaline monosulphides* and *sulphydrates*, forming sulphur-salts called sulphomolybdates; the alkaline disulphides do not dissolve it.

The sulphomolybdates are the analogues of the molybdates, most of them being constituted according to the formula $R^2S.MoS^3$ or R^2MoS^4. There are also a few containing 2 or 3 at. of the sulphur-acid. The sulphomolybdates of the alkali-metals, alkaline earth-metals, and magnesium, are soluble in water; the rest are insoluble. The alkali-metal salts are obtained by passing sulphydric acid gas into concentrated solutions of the corresponding molybdates; the insoluble salts by precipitating a neutral oxygen-salt of the metal with a soluble sulphomolybdate.

The aqueous solutions of neutral sulphomolybdates have a fine red colour when pure, changing to brown, however, if they contain a small quantity of iron or an excess of the sulphur acid. During evaporation, they emit a constant odour of sulphydric acid. When exposed to the air, they remain unaltered, if they contain an excess of the sulphur-acid; in the contrary case, the solutions—and likewise the dry salts—are rapidly oxidised, the sulphide of the alkali-metal being converted into hyposulphite, while the trisulphide of molybdenum is partly precipitated as such, partly converted into trioxide and blue oxide of molybdenum. The sulphomolybdates are decomposed by acids,

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with evolution of sulphydric acid and precipitatio
heated to redness, they yield molybdous sulphide
off 1 at. sulphur.

Sulphomolybdate of Ammonium, $(NH^4)^2M$
aqueous solution mixed with alcohol in cinnabar-c
on exposure to the air. The aqueous solution,
edges a number of crystals which are green by re
dries up to a black amorphous mass. The salt is

Bodenstatt (J. pr. Chem. lxxviii. 186; Jahre
dric acid gas to supersaturation into a solution
chloric acid, mixed with a large quantity of sal-amm
with ammonia, obtained deep red crystals of a *sul*

Sulphomolybdates of Barium.—The *neut*
dark red amorphous mass, from the mother-liquo
phomolybdate, $Ba''S.3MoS^3$ or $Ba''MoS^4.2MoS^3$, i
barium with an excess of molybdic trisulphide, a
cooling, in small yellow shining crystals, which,
shining powder of the same colour. They give
and are decomposed by dilute, but not by concent

The *cadmium-salt* is a dark brown precipita

An acid *calcium-salt*, probably $Ca''MoS^4.2M$
ing barium-salt, and crystallises in short, shining
crystals, permanent in air even at 100°; hydrochlo
the sulphide of molybdenum. The mother-liquor
the *neutral calcium-salt* in the form of a dark red

Cerous sulphomolybdate is a dark grey
sulphomolybdate to the solution of a ceric salt, on
ammonia throws down from the resulting yellow
brown gummy mass.

The *chromic salt* is a dark brown precipitate,
cobalt- and *copper-salts*, are dark brown preci
of potassium.

The *gold-salt* (*auric*) is soluble in water, whe
dark brown powder, becoming black when dry.

Iron-salts.—The *ferrous* salt is soluble in
which becomes darker and nearly black on exposu
shallow vessel, together with sulphomolybdate o
from the latter as a black jelly, which, as well as
red-yellow powder by spontaneous evaporation.
tate which dissolves, with black colour, in excess
ally separates again after 24 hours. When dry it

The *lead-salt* is a black precipitate, which wh
shining streak on paper.

Magnesium-salts.—By boiling molybdic tris
sium, and cooling, a dark brown powder is obtaine
date of magnesium. The supernatant liquid cont
a dark red varnish.

Manganese-salts.—By digesting sulphide o
trisulphide, a brownish-yellow liquid is obtaine
varnish. Ammonia throws down from the solution
by a larger quantity of ammonia. Sulphide of
molybdic trisulphide forms an insoluble compound

Mercury-salts.—*Mercurous sulphomolybdat*
a light brown precipitate. The *nickel-salt* resem
salt is a dark brown precipitate, black after dryi

Potassium-salts.—α. The *neutral salt*, K^2Mo
potassic carbonate, sulphur, charcoal powder and e
cible, gently at first, afterwards very strongly. The
after cooling, a dark red opaque solution. A simil
solution of potassic molybdate with sulphydric acid
vessel at 40°, it yields four and six-sided prisms
dark red by transmitted, but of a fine dark green
dark red powder, becoming green and shining
red aqueous solution, throws down a cinnaba
liquid deposits scales of the same colour which

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drying. The salt heated in an atmosphere of hydrogen is only partially decomposed into disulphide of potassium and molybdous sulphide.—*β.* Another salt containing a larger proportion of molybdic trisulphide, is precipitated as a brown-yellow powder, when the solution of the neutral salt is mixed with a quantity of acetic acid sufficient to give it an acid reaction. It is black after drying, and dissolves easily in boiling, slowly in cold water, forming a yellow solution. A solution of the neutral salt, mixed with a small quantity of any other acid, becomes darker, in consequence of the formation of this compound, but does not yield a precipitate.

A compound of *sulphomolybdate* and *nitrate of potassium* is obtained when a solution of equal parts of the two salts is left to evaporate. It then separates in green metallic-shining scales, very much like sulphomolybdate of potassium, which burn away like gunpowder when heated.

The *silver-salt* resembles the lead-salt in colour and streak.

Sodium-salts.—The *neutral salt* forms small dark red granular crystals, much more soluble in alcohol than the potassium-salt. It is almost completely reduced by ignition in hydrogen gas. There is also an *acid* sulphomolybdate of sodium, much less soluble than the neutral salt, and resembling the corresponding potassium-salt in all its properties.

The *strontium-salts* resemble the barium-salts.

The *uranium-* and *zinc-*salts are dark brown precipitates; the *stannous* salt is a black precipitate; the *stannic* salt, a translucent brown precipitate becoming grey-brown when dry.

Tetrasulphide of Molybdenum. *Persulphomolybdic acid*, MoS^4.—This sulphide is thrown down by hydrochloric acid from the solutions of alkaline persulphomolybdates, as a flocculent translucent precipitate of a fine dark red colour, shrinking together when dry, into a coarse-grained mass, possessing a dark green metallic lustre, and yielding a dark red powder when triturated with water. It is insoluble in water and in acids. When heated in a retort, it gives off water and a small quantity of sulphurous anhydride, then a large quantity of sulphur, and leaves disulphide of molybdenum.

Persulphomolybdates. Tetrasulphide of molybdenum unites with basic metallic sulphides, forming salts represented by the formula $R^2S.MoS^4 = R^2MoS^5$. Most of them are dark red and retain their colour unaltered when dry. The persulphomolybdates of the alkali-metals are soluble in water, and their solutions yield with acids a precipitate of molybdic tetrasulphide.

The *ammonium-salt* is obtained by drenching moist molybdic tetrasulphide with sulphydrate of ammonium, to which a little caustic ammonia may be advantageously added. A yellow powder is then formed, which becomes dark red when dry, is insoluble in alkaline liquids, sparingly soluble in cold, easily in hot water.

Barium-salt.—Yellow or red precipitate, insoluble in water, and not decomposed by dilute hydrochloric acid. The *calcium-salt* is precipitated after some time by alcohol from a mixture of the potassium-salt with chloride of calcium, as a cinnabar-coloured powder slightly soluble in water.

The *copper-salt* is a precipitate dark coloured at first, but becoming red inclining to brown after it is collected. The *gold-salt* (auric) is a brown precipitate which turns yellow and decomposes in drying, and when heated in contact with the air, burns, gives off sulphurous anhydride, assumes a golden-yellow colour, and when very strongly heated, yields a sublimate of molybdic trioxide.

Iron-salt.—Red precipitate formed on adding the potassium-salt to an excess of a ferrous salt.

The *lithium-salt* resembles the potassium-salt. The *magnesium-salt* is an insoluble red precipitate.—The *mercurous salt* is a dark almost brown precipitate.

Potassium-salts.—When sulphomolybdate of potassium is boiled with molybdic trisulphide (such a mixture is obtained by decomposing an acid molybdate of potassium with sulphydric acid), the boiling being continued for several hours in a retort, a large quantity of sulphydric acid is given off with the watery vapours, and a copious precipitate is formed. On collecting the precipitate after cooling on a filter and washing till the wash-water gives a dark red flocculent precipitate with hydrochloric acid, a residue is obtained from which water extracts persulphomolybdate of potassium, leaving disulphide of molybdenum behind. The resulting solution is red, and generally yields the salt on evaporation in the form of a red mass, having the consistence of an extract. On one occasion, however, Berzelius observed the salt to separate from the boiled mixture on cooling, in small ruby-coloured crystalline granules which could be separated from the rest of the precipitate by levigation. They appeared under the microscope as transversely striated rectangular scales; were

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insoluble in cold water, hydrochloric acid, and po
a low red heat, they decrepitated, gave off water
sulphydric acid, after which water extracted sulphi
disulphide of molybdenum.

When a dilute solution of sulphomolybdate
of molydic trisulphide is exposed to a heat o
gradually yields a lighter coloured deposit of persu
after drying, forms a yellow coherent mass cons
having a silky lustre. The same mass is obtai
sulphide with sulphydrate of potassium. It is in
water.

Persulphomolybdate of silver is a da
collected.

The *sodium-* and *strontium-salts* resem
respectively.

Tin-salts.—The *stannous salt* is obtained
decomposition, as a dark brown precipitate. If th
an open vessel, the stannic salt is formed and the
The *stannic salt* is only partially precipitated, th
same colour.

MOLYBDIN. Syn. with molybdic ochre, or

MOMORDICA. According to Lepine (J
charantia yields a solid fat melting at 65°.—On t
the fruit of *Momordica Elaterium* at different se
xi. 21).

MOMORDICIN. Syn. with ELATERIN (ii. 3

MONARDA, OIL OF. The essential oil
Monarda punctata. It easily separates into a liq
essence is a yellowish-red liquid, having an odo
after rectification with water, boiling at 224°, and
camphor or stearoptene, when purified by pressure
tals, melting at 48° and solidifying again at 38°.
analysis, is $C^{10}H^{14}O$; that of the oil separated f
$(C^{10}H^{14})^3O$. The crystals absorb 2 or 3 per ce
Ann. Ch. Pharm. lviii. 41; Handw. d. Chem. v. 3

MONAZITE. *Edwardsite, Mengite, Eremite*
thanum, also containing thorinum according to som
prisms, usually small and flattened. Ratio of ax
Angle of b and c = 76° 14′. Observed planes,
$-P$, ∞P, $[\infty P2]$, and others. Cleavage basal,
= 5 to 5·5. Specific gravity = 4·9 to 5·25.
hyacinth-red, or yellowish-brown colour, and resi
to subtranslucent and rather brittle. The miner
dissolves slowly in borax, forming a bead which
while hot, colourless when cold.

Analysis.—*a.* From Slatoust in the Ural; Broo
xlvii. 385).—*b.* The same (Hermann, J. pr.
Antioquia, in New Granada:

P^2O^5.	ThO.	CeO.	LaO.	CaO.	
28·50	17·95	24·78	23·40	1·68	
28·05	. .	37·36	27·41	1·46	
29·1	. .	46·4	21·5	. .	

The presence of thorinum in monazite has been
Hermann, on the contrary, denies it, and is of opi
formed in the analyses has been mistaken for sul
results may be represented by the formula (Ce; L
new analyses are required to fix the formula with

Monazite was first obtained from Slatoust. It
town in Connecticut; at Yorktown, Chester Coun
Mountain, North Carolina.

MONAZITOÏD. The name given by Her
variety of monazite from the Ural, distinguished

* With traces of titanic acid

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), and by the presence of tantalum. Hermann found in it 17·94 per
5 CeO, 21·30 LaO, 1·50 CaO, 1·36 H^2O, and 6·27 TaO^2. It gives off
of chlorine when treated with hydrochloric acid, and dissolves, leaving
ellow residue.

A compound resembling saponin, contained in an extractive substance
which appears to be obtained from the bark of *Chrysophyllum glycy-*
an plant of the sapotaceous order. (Desrone, Henry and Payen,
. xxxvii. 352.)

ITE. Syn. with KAPNITE (p. 445).

MPOUNDS. This term is applied to compounds containing 1 at. of
cified, *e.g.*, $C^2H^3ClO^2$, *monochloracetic acid*, $C^6H^5.H^2.N$, *monophenyl-*

NE. Syn. with EPISTILBITE (ii. 491).

PA. According to F. L. Winckler (N. Jahrb. Pharm. viii. 322), the
pa hypopitys, gathered when the flowers are almost fully expanded,
ion with water, a volatile oil identical with that of *Gaultheria procum-*
The residue of the distillation contained an acid.

TE. A magnesio-ferrous silicate from Bergen in Norway, where it
anular; also foliated, with one distinct and another imperfect cleavage
Hardness = 6 nearly. Specific gravity = 3·2673. It has a pale
lining to red, and a strong vitreous lustre. Contains 56·17 per cent.
nesia, 8·56 ferrous oxide, and 4·04 water (= 100·40, agreeing nearly
$4(\frac{3}{4}Mg.\frac{1}{4}Fe)^2SiO^2.H^2O$. (Erdmann, K. Vet. Acad. Handl. 1842;

TE. Syn. with KYANITE (p. 449).

NE. An alkaloïd said by Van Mons to exist in *China montana*, the
na floribundum. Winckler was not able to find it.

LITE. A variety of chrysolite (i. 958).

LLONITE. A rose-red, fragile, argillaceous substance found at
ar Confolens in Charente, and near St. Jean de Colle in Dordogne.
er cent. silica, 20·16 alumina, 0·68 ferric oxide, 1·46 lime, 0·23 mag-
, and 26·0 water. (Damour, Bull. Soc. geol. de France [2] iv. 464.)

TE. A variety of translucent felspar from Ceylon. (See FELSPAR,

E. See DYEING (ii. 352).

TE. A fibrous zeolite from the trap of the Bay of Fundy, Nova Scotia,
erived from Morden, a village near which it is found. It occurs in
or geodes of white, yellowish or pinkish colour, and strong silky
dull; cleaves readily in directions parallel to the fibres; is translu-
es. Hardness a little above 5. Specific gravity = 2·08. Rather
he blowpipe it fuses at a strong heat to a glassy bead, without intu-
ydrochloric acid it does not gelatinise but yields slimy silica. Contains
) 68·40 per cent. silica, 12·77 alumina, 3·46 lime, 2·35 soda, and 13·02
reeing very nearly with the formula, $(\frac{4}{5}Na.\frac{1}{5}Ca'')O.Al^2O^3.9SiO^2.6H^2O$,
to that of a metasilicate, $M^2(R^2)^{vi}H^{16}Si^9O^{27}.H^2O$. (How, Chem. Soc.

D. *Morin.* (R. Wagner, J. pr. Chem. li. 82; Hlasiwetz and
. xc. 445.)—An acid existing in old fustic (*Morus tinctoria*), and de-
um-salt, together with morintannic acid, from an infusion of the wood
xtract it, the deposit (sometimes called *morin*) is treated several times
ol; the alcoholic liquor is diluted with six times its bulk of water,
s the morate of calcium in the form of a yellow crystalline powder,
f the morintannic acid remains dissolved. The calcium-salt is then
g alcohol, the calcium precipitated by oxalic acid, and the moric acid
the hot filtrate by water, purified by re-solution in alcohol and re-
ater, and finally dried over the water-bath out of contact with air
siwetz and Pfaundler treat the deposit above mentioned twice with
ar pressing it, and thereby obtain a solution of morintannic acid
esidue consisting of crude moric acid and nitrate of calcium. This
with water and a little hydrochloric acid (to decompose the calcium-
l with water and dissolved in hot alcohol. The filtrate mixed with
volume of hot water, deposits the greater part of the moric acid
, which may be purified by solution in weak alcohol (using filters

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free from lime and iron), and formation of a sm
solution, to carry down resinous matters.

Moric acid is a white crystalline powder, which g
the air. According to Hlasiwetz and Pfaundler, i
long, mostly grouped in tufts. It is very sparin
pts. at 20° and 1060 pts. at 100° to dissolve it;
(Wagner), sparingly soluble in *ether*, insoluble
and Pfaundler). The solutions have a deep ye
Dried at 120°, it contains, according to Wagner, 6
gen, numbers which may be represented by the fo
sition differs but little from that of morintannic a
Pharm. 1862, p. 143) concludes, from his own ex
is nothing but morintannic acid contaminated w
hand, Wagner (Chem. Centr. 1862, p. 399) still
from morintannic acid, inasmuch as the former is
than the latter, and reacts differently with alkali
acids is further established by the experiments of

Moric acid bears a rather high temperature
blackens and gives off a considerable quantity of
yellow oil which partly concretes on cooling, and
oxyphenic acid (pyrocatechin). It dissolves in
strong *sulphuric acid* with brown-yellow colour,
original state. The sulphuric acid solution deco
phurous anhydride and phenol. Strong *nitric aci*
acid. With *caustic alkalis* and their *carbonates*
yellow colour: paper impregnated with it affords
solution does not precipitate *gelatin*, but it stains
colours the solution garnet-red (Wagner), deep oli
ler). A solution of moric acid boiled with *cupric*
potash, yields a precipitate of cuprous oxide. Fr
nitrate, it immediately reduces metallic silver.

Morate of Barium is produced by boiling the
bonate of barium: the resulting solution when ev
of a red-brown powder, apparently containing 3(
cium-salt exists ready formed in fustic, and is dep
sulphur-yellow crystals which apparently contain
water at 100°. (Wagner.)

MORINDIN. A substance obtained by An
435; Ann. Ch. Pharm. lxxi. 216) from the root of
the Hindoos, frequently used as a dye-stuff in th
root is exhausted with boiling alcohol, the first
morindin contaminated with a red colouring matt
small radiated yellow crystals. The whole is puri
dilute alcohol slightly acidulated with hydrochlori

Morindin forms crystals having a fine yellow c
ingly soluble in cold, more soluble in boiling *alco*
lute alcohol it is less soluble, and quite insoluble in
sparingly, sufficiently however to acquire a yello
easily, and deposits it on cooling as a gelatinous ma

Morindin dried at 100° gives by analysis 55·4
whence Anderson deduces the formula $C^{28}H^{15}O^{15}$
C, 4·9 H, and 39·6 O). Rochleder regards it as
(54·5 C, 5·2 H, 40·3 O), which he obtained from

Morindin dissolves in *alkalis*, forming orange-re
colours it deep purple, or violet in thin layers; the
24 hours, deposits yellow flocks of unaltered subst
and forming with ammonia, not an orange-red, bu

Nitric acid of specific gravity 1·38 dissolves mo
a deep red colour; on heating the liquid, a brisk
boiled with nitric acid and neutralised with ammo

Basic acetate of lead precipitates morindin in
stable and cannot be washed without loss of colo
strontia and *lime* form bulky precipitates sparingl

Ferric chloride produces a brown coloration, b
solution of morindin forms with *alum* a reddish li
cipitate having the colour of ferric oxide.

Morindin heated in a close vessel melts and boils

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se in long slender yellowish-red needles of alizarin (Anderson's

ered morinda-root is boiled with moderately dilute *sulphuric acid*, as in arancin process, its morindin is converted into alizarin; but the large own matter produced at the same time, greatly diminishes the value of btained, as it renders the colours dull and the whites difficult to clear. t is therefore never likely to compete successfully with madder, at least vertheless it affords the best known source of pure alizarin, this sub- repared from it, being quite free from purpurin, which, as is well known, lt to separate completely from the alizarin prepared from ordinary enhouse, Chem. Soc. J. xvii. 334.)

ONE. See the last article.

IC ACID. $C^{18}H^{28}O^2$.—An oily acid, homologous with oleic acid, ther with stearic, palmitic and benic acids, by the saponification of oil of *aptera*). It is colourless or faintly yellow, has a density of 0·908, a which irritates the throat, and a faint odour. It reddens litmus paper; in common alcohol, even in the cold; solidifies at the freezing point of mposed by heating with sulphuric acid. Walter found in it 75·0 per nd 11·7 hydrogen, the above formula requiring 74·9 C, 11·8 H, and *hardt's Traité de Chim. org.* ii. 882.)

ANNIC ACID. *Maclurin.* $C^{13}H^{10}O^6$. (R. Wagner, J. pr. Chem. wetz and Pfaundler, *ibid.* xc. 445; Jahresb. 1863, p. 594.)—A variety which constitutes the chief colouring matter of old fustic (*Morus tinctoria*, Hlasiwetz and Pfaundler, *Maclura tinctoria*). It forms a large portion found in the interior of faggots of that wood, and may be obtained by deposits with boiling water and leaving the extract to cool. The acid is in the form of powder and may be purified by crystallising it several e water, and dissolving the crystalline deposit in water slightly acidulated ric acid, to separate a resinous substance, and filtering the solution when turbid. (Wagner.)

oncentrated aqueous decoction of fustic left to itself for some days yields rystalline deposit, which when pressed and twice boiled with water e consisting of crude moric acid and morate of calcium, and a solution of id, which deposits a portion of the acid on evaporation, the rest on addi- hloric acid. It may be freed from resinous impurities, first by crystal- water acidulated with hydrochloric acid, and finally by adding to the all quantity of acetate of lead, and precipitating with sulphydric acid in e acetic acid. (Hlasiwetz and Pfaundler.)

acid is deposited from its solution as a light yellow crystalline powder, icroscopic prisms. It dissolves in 64 pts. of cold, and 2·14 pts. of boiling ion having a slight acid reaction, and sweetish astringent taste; easily also *d-spirit, and ether;* but is insoluble in oil of turpentine and in fixed ereal solution is greenish by reflected and brown by transmitted light.

ition of morintannic acid is shown by the following analyses and

At 130°—140°.				At 100°.		
on.	Hlasiwetz and Pfaundler.			*Calculation.*	Wagner. *mean.*	Delffs.
9·54	59·36	59·25	C^{13}	55·71	55·17	54·1
3·81	4·13	4·18	H^{12}	4·29	4·41	4·4
6·65	36·51	36·57	O^7	40·00	40·42	41·5
0·00	100·00	100·00	$C^{13}H^{10}O^6.H^2O$	100·00	100·00	100·0

ds the compound dried at 100° as identical with moric acid; but as ed (p. 1047), the difference between the two acids may be considered as ablished by the recent researches of Hlasiwetz and Pfaundler.

e acid melts at 200°, blackens and gives off water and acid vapours at ergoes complete decomposition at 270°, yielding a large quantity of car- de, and an oily distillate which partly solidifies on cooling, and leaving a The distilled oil is a mixture of phenol and pyrocatechin. (Wagner.)

s solution of morintannic acid is not precipitated by hydrochloric, sulphu- e or arsenic acid, but completely by *gelatin* and softened *animal bladder*. e acid dissolves in cold strong *sulphuric acid*, forming a yellow solution is precipitated by water; on heating the solution, it blackens and gives off ydride and phenol. The solution in cold sulphuric acid, if left to itself for

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some days, yields a brick-red deposit of rufimor
after a while from the solution of morintannic a
By boiling concentrated hydrochloric acid, and b
decomposed, giving off the odour of phenol. W
phuric acid, it gives off a large quantity of carb
acid. Strong *nitric acid* converts it into styphn
composes it easily and completely. *Chlorine* pa
down yellow resinous flocks. (Wagner.)

The acid mixed with a solution of 3 pts. *hydra*
silver dish till it has become pasty is resolved
techuic acid. (Hlasiwetz and Pfaundler

$$\underset{\text{Morintannic acid.}}{C^{13}H^{10}O^6} + H^2O = C^6$$
Ph
gl

Morintannates. Morintannic acid unites dire
poses the alkaline and earthy carbonates when
the alkaline morintannates are yellow, but quickl
the air, so that these salts cannot be obtained pu
the acid forms a greenish precipitate with *ferros*
of lead, brown with *potassio-antimonic tartrate*,
yellowish-red with *stannous chloride*, yellow and
does not immediately precipitate a solution of *al*
sium, a yellow lake is thrown down.

A moderately concentrated solution of morinta
with a dilute solution of *neutral lead-acetate*, and
laminar crystals containing, when dried at 110°,
out alteration, 33·09 per cent. carbon, 2·00 hydr
with the formula $C^{26}H^{18}Pb''O^{12}.Pb''H^2O^2$, which
PbO (Hlasiwetz and Pfaundler). Wagne
32·01 per cent. C, 2·17 H, and 44·27 PbO, wh
$C^{26}H^{18}Pb''O^{18}.Pb''H^2O^2 + H^2O$.

MOROXITE. A greenish-blue variety of
and Pargas in Finland.

MOROXYLIC ACID. A volatile crystall
as a calcium-salt in the stems of the mulberry
the same calcium-salt in the so-called *Lachrym*
stems. (Handw. d. Chem. v. 142.)

MORPHETINE. A product of the oxidati

MORPHINE, or **MORPHIA.** $C^{17}H^{19}NO^3$
of the opium-bases, was known in an impure stat
teenth century; but it was not obtained as a well
Sertürner published a series of important resea
192; lix. 50). It has been further examined by R
li. 232); Pelletier and Caventou (*ibid.* xii.
xxiv. 182); Lassaigne (*ibid.* xxv. 102); Dubl
xlvii. 105; Ann. Ch. Pharm. xxvi. 41); Merck (
xxiv. 46); Regnault (Ann. Ch. Phys. [2] lxviii.
Lefort (J. Pharm. [3] xl. 97); and Guibour
opium generally contains from 10 to 15 per cen
5·8 to 6·6 per cent.; East Indian from 5·3 to 7·7 p

Preparation.—1. Opium is exhausted with cold
to a syrup at a gentle heat, is heated while yet w
of sodium as long as ammonia continues to escape
after twenty-four hours, and washed with cold wa
longer coloured, the precipitate is treated with alc
exhausted in the cold with very dilute acetic acid,
acid at once, and to wait till each portion is neutr
lution is then filtered, decolorised with animal ch
care being taken to avoid an excess; and the precip
solved in boiling alcohol. The liquid on cooling c
additional quantity may be obtained by concentra

2. Twenty pts. of opium cut in slices are boiled
or until all the slices are opened out; the liquid i
squeezed and again twice treated with fresh wate
tracts are boiled down to half their bulk, then sti
of 3 pts. slaked lime and 40 pts. water; the liquid

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ed; and the calcareous residue is pressed and again twice boiled in 50
e whole of the calcareous liquors are now boiled down to 40 pts. and
g heat with 2 pts. sal-ammoniac; the heat is kept up for an hour, or as
a is given off; the liquid is then allowed to cool; and after eight days the
h separates in the form of brown granules, is collected: the mother-liquor
rop if further boiled down and left to itself. The product may be purified
cold water, solution in hydrochloric acid, repeated boiling with excess of
d precipitation with sal-ammoniac. (Mohr, Ann. Ch. Pharm. xxxv. 120.)
ess most generally employed is that of Robertson, modified by
l Gregory (Ann. Ch. Pharm. v. 87; vii. 261).—Opium is macerated in
ill all the soluble principles are extracted; the solution is evaporated
of calcium, which neutralises the free acids; and when the liquid is
centrated, chloride of calcium is added, whereby a precipitate of meco-
n is formed, which carries down with it a considerable quantity of
r. The opium bases remain in the solution as hydrochlorates, and the
ain concentrated, first deposits more meconate of calcium, and afterwards
rochlorate of morphine mixed with hydrochlorate of codeine. These
purified by repeated crystallisation, with addition of animal charcoal.
drochlorates are next dissolved in water and treated with ammonia,
ates the morphine, leaving the codeine dissolved. The morphine is
by crystallisation from alcohol.

epared by either of the preceding processes is often contaminated with nar-
ich however it may be freed by either of the following processes:—1. By
ter, which dissolves narcotine much more easily than morphine.—2. By
ixed bases in hydrochloric acid, evaporating to the crystallising point, and
ystals, which consist entirely of hydrochlorate of morphine, the narcotine-
in the uncrystallisable mother-liquor.—3. By mixing the hydrochloric
ith common salt, which renders the liquid milky, and throws down the
some days in crystalline agglomerations; the morphine may then be
ammonia.—4. By pouring a weak solution of caustic potash into the
of the hydrochlorates; the morphine then dissolves in a slight excess of
he narcotine is deposited as a curdy precipitate, which may be separated

ccount of the various methods used for the preparation and purification
ee *Gmelin's Handbook*, xvi. 416–423.

-Morphine crystallises in colourless transparent prisms usually very short,
e trimetric system. Observed combination: ∞P . $\infty \breve{P}\infty$. $\breve{P}\infty$. Angle
27° 30′; $\infty P : \infty \breve{P}\infty = 116° 20′$; $\breve{P}\infty : \infty \breve{P}\infty = 132° 20′$; $\breve{P}\infty : \breve{P}\infty$
leavage parallel to $\infty \breve{P}\infty$. It is inodorous but has a persistently bitter
xtremely poisonous, exerting a strong narcotic action. In small doses it
n medicine as a sedative.

but very slightly soluble in cold *water*; boiling water dissolves about $\frac{1}{50}$ of
he greater part of it in the crystalline form as it cools. Cold *alcohol*
ttle of it; boiling alcohol a larger quantity. It is insoluble in *ether*, and
sily separated from narcotine, which is dissolved by ether. Morphine is
ble in *volatile oils*. Aqueous *alkalis*, even *lime-water*, dissolve it readily;
ever, but sparingly.

rns the plane of polarisation of a luminous ray to the left. In the state
l solution in water acidulated with hydrochloric acid, its molecular rota-
expressed by $[\alpha] = -88{\cdot}04$. It has likewise about the same amount of
when dissolved in alcohol.

s of morphine melt when heated, giving off 5·94 per cent. (= 1 at.)
llisation; at a high temperature they become carbonised.

ition of morphine dried at 120° is expressed by the formula $C^{17}H^{19}NO^3$,
he following results of analysis:

	Liebig.*		Regnault.†			Will.‡	Laurent.§	
71·58	71·35	71·38	71·87	71·41	71·66	71·40	71·63	71·59
6·66	6·69	6·77	6·86	6·84	6·86	6·72	6·58	6·66
4·91	4·99	. .	5·01					
16·85	16·97							
00·00	100·00							

led pseudomorphine or phormine, occasionally, found by Pelletier
extract of opium containing a large quantity of narcotine, and the meta-
Wittstein, found on one occasion only in the residue of the preparation

n. Ch. Pharm. xxvi. 41.
d. xxvi. 44.

† Ann. Ch. Phys. lxviii. 131.
‡ *Ibid.* [3] xix. 869.

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of opium-tincture, were probably nothing but imp
book, xvi. 440.)

Reactions.—Morphine and its salts are very sens
1. *Iodic acid* is reduced by morphine either free o
and emitting an odour of iodine. This reaction
morphine in 7000 pts. of liquid (Serullas). *P*
Ammonia deepens the colour of a solution of i
J. Pharm. [3] xl. 97). When solid morphine or
solution of 1 pt. iodic acid in 15 pts. water, and
water is added, a blue colour is produced, by whi
if a drop of the starch-solution be previously eva
tion will suffice for the detection of $\frac{1}{10,000}$th of a g
nia be poured upon a solution of morphine mix
even if only $\frac{1}{20,000}$ pt. of morphine is present, two
surface of contact, the upper being blue, the lowe
the brown ring is produced. Other substances ca
wise produce the blue ring, but not the brown r
Chem. News, viii. 267; Jahresb. 1863, p. 704.)

2. Morphine and its salts slowly reduce *nitrat*
3. *Chloride of gold* colours them blue, from red
4. They reduce *permanganate of potassium*, wh
5. *Ferric salts* impart to morphine and its solu
not permanent, and is destroyed by excess of acid
This reaction is characteristic of morphine (Ro
sulphuric acid previously heated is coloured de
changing after a while to dirty green. (Husem
6. When sulphate of morphine mixed with dil
oxide of lead, till the liquid is no longer precipitate
acid then removed by carbonate of lead, and the
filtered liquid yields on evaporation a brown amo
phetine), which reddens litmus, is soluble in wate
acquires a darker colour by contact with alkalis,
lead. By continued action of the peroxide of le
quescent acid body.

7. *Nitric acid* communicates to morphine an ora
yellow. In this reaction, an acid body is produ
gives off a volatile oil. (Anderson, Ann. Ch. P
8. Warm dilute *sulphuric acid* converts morphi
9. Morphine dissolved in strong sulphuric acid
a violet-red solution (J. Erdmann, Ann. Ch.
Husemann (*ibid.* cxxviii. 305), this reaction ma
delicate by first dissolving the base in strong
0·002 to 0·004 grm. to 6 or 8 drops of the acid, a
whereupon, if the morphine-solution has been red
duced, changing after a few seconds to yellow, th
If a small qnantity of water be added to the solut
so that the mixture becomes hot, the colouring pr
nitric acid is of a much deeper carmine-red, and
tion be heated for a few miuutes to 100°—150°,
produces, after cooling, a splendid deep violet col
the centre outwards, passing through blood-red.
150°, the liquid acquires of itself at a certain m
higher temperatures, a dirty green colour is pro
acid, after cooling, the liquid immediately turns
A solution of morphine in sulphuric acid, left to
temperatures, behaves as if it had been heated to

Hypochlorite of sodium, *chlorine-water*, and *chl*
phine the same reactions as nitric acid.

With regard to the sensibility of these reactions
gramme of morphine is sufficient to produce a very b
a very distinct reaction, and $\frac{1}{100}$th mgr. still gives

10. When *chlorine* is passed into water containi
phine first acquires an orange colour, then dissolv
the chlorine be continued, the liquid turns yellow,
alcohol. (Pelletier.)

11. *Iodine* unites with morphine, forming the s

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to 200° with excess of *hydrate of potassium*, yields an alkaline dis-
methylamine.
heated with the *iodides of methyl* and *ethyl*, yields hydriodate of
or of ethyl-morphine.
presence of morphine when mixed with animal matter, the substance
umina, dried between 100° and 110°, then well pulverised and mace-
ter acidulated with acetic acid. The solution treated with ammonia,
e, which may then be recognised by the characters above described,
reactions with iodic acid, ferric salts, and nitric acid.

Morphine in Opium.—15 grms. of opium cut in pieces are triturated
ohol of 71 per cent.; the solution is strained through linen; and the
ng pressed, is again treated in the same way with 40 grms. alcohol.
ncture mixed with 4 grms. of aqueous ammonia yields in 12 hours
hine and narcotine, which are collected, washed several times with
d up in the water; the crystals of morphine then sink to the bottom,
arcotine, being lighter, remain longer suspended and may be separated
Guillermond, J. Pharm. [3] xvi. 17). Riegel (Jahrb. pr. Pharm.
es the narcotine precipitated together with the morphine, by washing
h chloroform. According to Reveil and Guibourt, the quantity of
by Guillermond is not sufficient for the exhaustion of the opium, and
ne enough for complete crystallisation. Guibourt therefore treats dry
or the aqueous extract of opium, with alcohol, either warm or cold,
her case to stand in the cold for 24 hours, to permit the separation of
x, and a portion of the narcotine. The tincture is drawn off with a
ue washed with alcohol, and the entire liquid precipitated by a slight
nia. After evaporation of the excess of ammonia, the morphine is
llise out completely, then collected and washed with alcohol of 50 per
with alcohol of 40 per cent., and finally with ether. The extract
ld water from 20 to 30 grms. of opium may also be redissolved in cold
ion precipitated by ammonia; and the precipitate collected after 36
th cold water, then with alcohol of 40 or 50 per cent., and crystallised
hol of 85 per cent. (Guibourt.)

(Am. J. Pharm. xxxv. 28) has given a volumetric process for estimat-
d other alkaloïds founded on their precipitability by *potassio-mercuric*
ndard solution contains 13·546 grms. ($\frac{1}{10}$ at.) mercuric chloride and
e of potassium in a litre; it is to be added to the solution to be tested
rary), and gives a perceptible precipitate with 1 pt. of morphine in 2500
e formation of the precipitate is not interfered with by extractive
prevented by alcohol, ammonia, and acetic acid; to obtain greater
cess of the precipitant may be estimated by a standard silver-solution.
ation of morphine, see further:—Fordos (Compt. rend. xliv. 1256;
b. 1857, 603); Meurein (J. Pharm. [3] xxiii. 176 and 262); L.
Ch. Pharm. ciii. 271); A. Petit (J. Pharm. [3] xliii. 45); on an older
lermond, see J. Pharm. xiv. 436.
on and identification of morphine in cases of poisoning, see Lassaigne
. [2] xxv. 102); Mermer (J. Chim. xxiii. 12); Stas (J. Pharm.
Flandin (Compt. rend. xxxvi. 517); Otto (Ann. Ch. Pharm. c. 46);
J. Erdmann (Ann. Ch. Pharm. cxx. 121); J. Erdmann (Ann.
xii. 360); Helvig, *Das Mikroscop in der Toxicologie*, Maintz, 1864,
rticle, ALKALOÏDS, in this Dictionary, i. 126.

Morphine.—Morphine dissolves easily even in dilute acids, forming
salts. It decomposes certain salts of lead, iron, copper, and mercury,
their acids. Most morphine-salts are crystallisable, inodorous, bitter,
us; they are soluble in water and in common alcohol, insoluble in ether,
alcohol. The solutions exhibit the reactions above described for
ording to Lassaigne and Feneulle, they deposit in the circuit of the
needles of morphine at the negative, and the acid at the positive pole.
olutions mixed with *ammonia*, *potash*, *soda*, *baryta*, *lime*, or *magnesia*
e as a crystalline powder soluble in excess of the precipitant, except
magnesia, difficultly soluble in excess of ammonia. According to
Pharm. [3] xiii. 143), the precipitate formed by ammonia is composed
hombohedral crystals. Morphine-salts are precipitated by the *neutral*
e alkali-metals, and the precipitate is not soluble in excess. The *acid*
e alkali-metals precipitate only a portion of the morphine from neutral
and do not form any precipitate in cold acid solutions. *Tartaric acid*
ecipitation of morphine by the acid carbonates of the alkali-metals.
Compt. rend. xxi. 210.)

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With *fluosilicic alcohol* (a saturated alcoholic soluti
salts yield a crystalline precipitate; with *phosphom*
flocculent precipitate; they are also precipitated by
sodic tungstate and phosphoric acid), and by *p*
dropping pentachloride of antimony into aqueous pl
the solution is diluted 1000 times. (F. Schultze.)

Acetate of Morphine crystallises by spo
needles very soluble in water, less soluble in alcoh
by heat, is partly decomposed, giving off aceti
morphine; by rapid evaporation, however, a varnis

Aspartate of Morphine is a gummy mass
soluble in water.

Bromomercurate.—Resembles the iodomercu
similar manner. (Groves.)

Carbonate.—Morphine dissolves in water st
under pressure; and the solution cooled to a low
morphine in shortened prisms soluble in 4 pts.
Alkaline carbonates added to solutions of morphine

Chlorate of Morphine forms long slender
when heated, swelling up and carbonising.

Chlorhydrate or *Hydrochlorate of Mor*
tallises in silky fibres, soluble in 20 pts. of cold
still more soluble in alcohol.

The *chloromercurate*, $C^{17}H^{19}NO^3.HCl.2HgCl$
precipitate, on mixing the solutions of its compo
deposits, after a while, tufts of silky crystals, havin
sparingly soluble in water, alcohol and ether at o
in boiling alcohol, which deposits it in the cry
dissolves it easily and deposits it by spontaneous e

The *chloroplatinate*, $2(C^{17}H^{19}NO^3.HCl).PtCl$
precipitate; a certain quantity, however, remains d
evaporation at a gentle heat.

Croconate of Morphine is a dark yellow unc
water and in alcohol.

Cynoplatinate of Morphine, $2(C^{17}H^{19}NO^3.$
and potassium throws down from the aqueous so
amorphous curdy precipitate which soon becomes
solidify into a brilliant white mass. It forms sl
depressed discs consisting of small microscopic r
dry; becomes dark-yellow when heated and white
150° to a brownish-yellow mass, and when fu
cyanogen, and burns with a sooty flame. It does n
tion at 125°. (Schwartzenbach, Chem. Centr.

Cyanurate of Morphine forms tufts of lo
cyanuric acid, even when morphine is present in ex
tallisation, with formation of a white amorphous m

Fluorhydrate or *Hydrofluate of Morp*
sparingly soluble in water, insoluble in alcohol and

Formate.—Small bitter prisms fusible and easil

Gallotannate.—Morphine-salts form with ga
a white precipitate sparingly soluble in water, fre
mineral acids, soluble also in alcohol.

Hippurate.—Transparent amorphous mass.

Hydroferricyanate.—Aqueous ferricyanide
hydrochlorate of morphine forms, after a while,
precipitate (Dollfus); according to Neubaner,
is formed.—*Hydroferrocyanate.*—Hydroferro
alcoholic solution of morphine, after long standing
needles. (Dollfus.)

Iodhydrate or *Hydriodate*, $C^{17}H^{19}NO^3.HI$
of 1 pt. iodide of potassium and 2 pts. acet
prisms are obtained, moderately soluble in wate
iodine. (Winckler.)

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rates.—Iodomercurate of potassium throws down from aqueous sulphate te of morphine, a pulverulent precipitate, which soon becomes gelatinous, e in hydrochloric acid (v. Planta, Delffs). When morphine, mercuric odide of potassium are brought together in aqueous solution, a double ^{3}.HgI^{2} [or $C^{17}NH^{19}O^{3}.HI.Hg^{7}I^{2}$?] is precipitated, sparingly soluble in luble in alcohol. It is crystallisable, free from water of crystallisation, ed by dilute acids, even on boiling, or on addition of iodide of potas- osed by caustic alkalis. (Groves, Chem. Soc. J. xi. 97.)

Morphine is a transparent gum exhibiting traces of crystallisation.

of Morphine is uncrystallisable, very soluble in water and in alcohol; salts. This salt is contained in aqueous extract of opium.

$C^{17}H^{19}NO^{3}.C^{4}H^{2}O^{4}$.—The solution of morphine in hot concentrated tic acid soon deposits white, microscopic, needle-shaped crystals, which cent. of their weight at 110°. They are rather more soluble in cold ter, freely in aqueous ammonia and potash, not in alcohol or in ether Ann. Ch. Pharm. lxxxi. 171). A *dibasic mellitate* appears to be formed, orphous brittle mass, when cold aqueous mellitic acid is saturated with the solution is evaporated. (Karmrodt.)

Morphine forms stellate rays soluble in 1½ pt. water.

Recently precipitated pectic acid dissolves morphine, even in the cold, k gum which, after dilution with water, is thickened again by acids.)

s.—Two phosphates of morphine appear to exist, the neutral salt crystal- , the acid salt in tufts. Phosphate of sodium added to solutions of mor- ms a crystalline precipitate very soluble in hydrochloric acid.

Picric acid forms with morphine-salts a sulphur-yellow pulverulent pre anta); no precipitate with the acetate. (Merck.)

ate.—Fissured gum, soluble in water and in alcohol. (Arppe.)

ate.—Hyacinth-red; soluble, with reddish colour, in water and in ler.)

.—The *neutral salt* $(C^{17}H^{19}NO^{3})^{2}.H^{2}SO^{4}.10H^{2}O$, crystallises in tufts of ms, very soluble in water and having a silky lustre. They give off 11·87 0 at.) water at 130°. There appears also to exist an *acid* sulphate of ch is obtained by supersaturating the preceding salt with sulphuric acid, dryness, and removing the excess of acid with ether.

hine is dissolved in dilute sulphuric acid, the solution evaporated till it mpose, and cold water then poured into it, a substance called sulpho- precipitated, having a constitution similar to that of an amide—that is be regarded as produced from sulphate of morphine by elimination of

$$\underset{\text{Sulphate of morphine.}}{(C^{17}H^{19}NO^{3})^{2}H^{2}SO^{4}} - 2H^{2}O = \underset{\text{Sulphomorphide.}}{C^{34}H^{36}N^{2}O^{6}S}.$$

hide recently prepared is white and amorphous, but soon turns green tubes. It dissolves in dilute acid and alkaline liquids. Strong acids compose it, forming a brown substance.

anate, $C^{17}H^{19}NO^{3}.CyHS$.—An alcoholic solution of morphine saturated ly concentrated sulphocyanic acid yields small, shining, limpid needles 100°.

tions of morphine are not precipitated by sulphocyanate of potassium.

. α. Neutral, $C^{17}H^{19}NO^{3}.C^{4}H^{6}O^{6}.3H^{2}O$.—When a solution of cream of alised with morphine, cream of tartar crystallises out first, then nodules e-salt, which must be removed in time, so as to keep them separate from rtrate of potassium which afterwards crystallises out. The salt may d by slow evaporation of an aqueous solution of tartaric acid neutralised . It forms nodular groups of crystals consisting of closely aggregated esces on the surface at 20°; loses on the average 6·54 per cent. water at 6·8 per cent.), no more at 145°. Exhibits crystal-electricity (ii. 411) o 130° or 140°, and retains it for an hour after cooling. Soluble in alcohol. ned aqueous solution is not precipitated by caustic alkalis, alkaline carbo- e of calcium, or ammonio-chloride of calcium. (Arppe, J. pr. Chem.

t, $C^{17}H^{19}NO^{3}.C^{4}H^{6}O^{6}.\frac{1}{2}H^{2}O$.—Obtained by mixing the solution of the th as much tartaric acid as it already contains. Crystallises by spon- ration in tufts of long rectangular flattened prisms. The air-dried salt per cent. (½ at.) water at 140°.

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Urate of Morphine is obtained by boiling uri
crystallises on cooling from a solution saturated at
prisms which decompose when recrystallised. (El

Valerate of Morphine forms fine large c
smelling strongly of valerianic acid. The crystals
are always hemihedral. Observed combination ∞P.
approximately, ∞P : ∞P = 100°; P̆ : P̆∞ = 125°
= 130°. (Pasteur, Ann. Ch. Phys. [3] xxxviii. 4

Derivatives of Morp

Iodomorphine, $4C^{17}H^{19}NO^3.3I^2$ (?).—A mixtu
phine dissolves completely at the boiling heat, form
taneous evaporation deposits this compound in the
mother-liquor retaining hydriodate of morphine.
heating a solution of sulphate of morphine with iodi
liquids when heated therein. It gives by analysis
requiring 39·87 per cent.

Iodomorphine triturated with metallic mercury a
its iodine to the mercury, and is converted into a y
cold water, sparingly soluble in boiling water, m
soluble in alkaline liquids, insoluble in acids. Trea
large quantity of iodide of silver. It melts when h
any trace of iodine. (Pelletier, Ann. Ch. Phys.

Methyl and Ethyl-morphine. The iod
morphine, producing hydriodates of bases in which
is replaced by ethyl or methyl.

Hydriodate of Methyl-morphine, $C^{17}H^{18}(CH^3)N$
water, and is deposited on cooling in colourless re
per cent. water (= 1 at.). The solution treated w
amorphous mass, which is quickly attacked by iodi

Hydriodate of Ethyl-morphine, $C^{17}H^{18}(C^2H^5)N$
morphine with iodide of ethyl and a small quanti
tube, is very soluble in boiling water, and crystalli
containing 1·98 per cent. water. It is sparingly
soluble in ordinary spirit, permanent in the air. T
tated by potash or ammonia. Hence this salt is p
thyl-ammonium, and the group $C^{17}H^{19}O^3$ in morphi
hydrogen.

The hydriodate is decomposed by oxide of silver,
when evaporated leaves a dark brown amorphous
J. vi. 125.)

MORPHIUM. Syn. with Morphine.

MORPHOLITES. Earthy concretions found
between 47 and 49 per cent. carbonate of calcium
laminæ of unequal thickness and dissimilar colours.

MORTAR. See *Ure's Dictionary of Arts, Ma*

MORVENITE. A brilliant variety of baryta
Argyleshire (p. 13).

MOSAIC GOLD. *Or molu.* An alloy of co
Copper, Alloys of, ii. 49.)

MOSANDRITE. A silico-titanate of ceriu
masses and imperfectly developed (monoclinic?) pri
phane, titaniferous iron, fluor-spar, &c., in the syen
järet, at the entrance of the Langesundfjord, near
red-brown colour, vitreous to fatty lustre, and is usu
ness = 4. Specific gravity = 2·93 to 2·98. Co
titanic anhydride, 26·56 oxides of cerium, lanthanu
0·75 magnesia, 19·07 lime, 0·52 potash, 2·87 so
(Erdmann, Berz. Jahresb. xxi. 178.)

MOSS AGATE. See Agate (i. 62).

MOTHER-LIQUOR or *Mother-water.* The
remains after the less soluble salts or other bodies

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-OF-PEARL. The hard silvery brilliant internal layer of several especially oyster shells, often exhibiting brilliant iridescence arising ed structure of its surface (see LIGHT, p. 608). It contains about 66 per e of calcium, 2·5 organic matter, and 31·5 water.

IN CORK or **MOUNTAIN LEATHER.** A variety of asbestos ibres are so interlaced that the fibrous structure is not apparent.

IN BLUE. Syn. with AZURITE. (See CARBONATES, i. 783.)

IN GREEN. Syn. with MALACHITE. (See CARBONATES, i. 783.)

IN SOAP. See STRATITE.

DE. $C^6H^{12}N^2O^6 = (C^6H^4O^2)^{vi}\left.\begin{matrix}H^4\\H^4\end{matrix}\right\}\begin{matrix}O^4\\N^2\end{matrix}$ (Malaguti, Compt. rend. xxii.

ed by the action of ammonia on mucic ether. It is white, very slightly ng water, and separates on cooling in microscopic crystals having the hedron with rhombic base, truncated on both summits, and looking like . It is tasteless and insoluble both in alcohol and in ether. Specific t 13·5°. Heated with water to 136°–140°, it is converted into mucate

$$C^6H^{12}N^2O^6 + 2H^2O = C^6H^8(NH^4)^2O^8.$$

ution of mucamide mixed with ammoniacal acetate of lead forms a pre- moniacal mucate of lead or *mucate of lead and plumbammonium*, $^6Pb'')O^{16}.6H^2O$. A boiling saturated solution of mucamide forms with rate of silver a specular deposit of metallic silver.

rns brown when heated a few degrees above 200°, and yields by dry ter, dipyromucamide, a small quantity of pyromucic acid, carbonic l carbonate of ammonium; the residue contains carbon and para-

CID. $C^6H^{10}O^8 = (C^6H^4O^2)^{vi}\left.\begin{matrix}H^4\\H^2\end{matrix}\right\}O^6$.—This acid, isomeric with saccharic

vered by Scheele in 1780, and has been examined chiefly by Laugier li. 79); Berzelius (*ibid.* xcii. 141; xciv. 5; xcv. 31); Malaguti . [2] lx. 195; lxiii. 86); Liebig and Pelouze (Ann. Ch. Pharm. xix. (*ibid.* xxvi. 16) Hagen (Pogg. Ann. lxxi. 531); Johnson (Ann. Ch. 5); and Schwanert (*ibid.* cxvi. 227); see also Gm. xi. 502; Gerh. ii. 143.

d was formerly represented by the diatomic formula $\left.\begin{matrix}(C^6H^8O^6)''\\H^2\end{matrix}\right\}O^2$, but to the sugars, it is now regarded as derived from the hexatomic alcohol substitution of 2 at. O for 4 at. H, being accordingly represented by $\left.\begin{matrix}H^4\\(C^6H^4O^2)^{vi}\end{matrix}\right\}O^6$, the number of its basic hydrogen-atoms being, as in other

qual to the number of oxygen-atoms which have entered into it by Kekulé, *Lehrbuch*, ii. 237.)

s formed by the oxidation of milk-sugar, lactose or galactose (p. 1023), e, and various kinds of gum (viz. gum-arabic, tragacanth, &c.). It is eating milk-sugar with moderately dilute nitric acid. According to r (Ann. Ch. Pharm. lxiv. 348), the best proportions are 1 pt. milk- nitric acid of specific gravity 1·42, the vessel being warmed till the , then cooled, and afterwards gently warmed towards the end of the roduct thus obtained, amounts to 60—65 per cent. of the milk-sugar cording to Pasteur, lactose treated with nitric acid yields twice acid as milk-sugar. Gum-arabic may also be used for the prepara- id, 1 pt. of it being heated with 4 pts. nitric acid of specific gravity 1·35; is obtained contains calcium-salts.

acid is purified by recrystallisation from boiling water, or better, espe- been prepared from gum, by dissolving it in ammonia, repeatedly e ammonium-salt from boiling water, and finally precipitating the the solution by nitric acid at the boiling heat.

ystallises in colourless tables with square base. It is sparingly soluble oluble in 6 pts. of boiling water, and insoluble in *alcohol*. *Sulphuric* with crimson colour.

oiled for some time with water undergoes an isomeric transformation, d into an acid (**paramucic acid**) more soluble and more energetic

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than mucic acid: its salts are also more soluble tha
in boiling water deposit mucates on cooling.

Mucic acid heated *per se* first melts, and then
products, pyromucic acid and carbonic anhydrid

$$C^6H^{10}O^8 = C^5H^4O^3 + C$$

When oxidised by boiling with *nitric acid*, it yields
Distilled with *sulphuric acid* and *peroxide of mang*
heating with caustic *potash*, it is converted into a m

$$C^6H^{10}O^8 = 2C^2H^4O^2 +$$

Mucic acid is converted by *pentachlorides of p*
chlorinated acid, $C^6H^4Cl^2O^4$, which has not been tho
stands to mucic acid in the same relation as chloro
acid, $C^4H^6O^6$ (Liès-Bodart, Ann. Ch. Pharm. c. 3
driodic acid is converted into an acid having the co
(Crum Brown, Ann. Ch. Pharm. cxxv. 19.)

Mucates. Mucic acid is dibasic. Its salts
the form $C^6H^8M^2O^8$; but a few acid mucates of
The alkali-metal mucates are very soluble in wat
The soluble mucates are decomposed by acids, wi
mucates when heated give off the odour of caramel.

Mucates of Ammonium.—The *neutral salt*, C
saturating the hot solution of the acid with ammon
salt which forms on cooling. The crystals are
which become soft and yellow at 220°, and betwee
water, carbonic anhydride, carbonate of ammoni
mucamide, while small quantities of charcoal and p

$$\underset{\text{Mucate of ammonium.}}{C^6H^8(NH^4)^2O^8} = \underset{\text{Pyromucic acid.}}{C^5H^4O^3} + C$$

$$\text{and } C^6H^8(NH^4)^2O^8 = \underset{\text{Dipyromucamide.}}{C^5H^3N^2O} +$$

Possibly the pyromucic acid, formed as in the manne
is converted into dipyromucamide by the action of t
at the same time.

Mucate of ammonium dissolves sparingly in
according to Malaguti, it is more soluble than the c

Acid mucate of ammonium, $C^6H^8(NH^4)O^8.H^2O$,
mucic acid with ammonia, and then adding an equal
colourless needles or thin prisms which, after dryin
per cent. water (= 1 at.) at 100°. It is more solu
and when distilled yields the same products, together
oil, which is soluble in water, appears to boil belo
when exposed to the air.

The mucates of *barium*, *strontium*, and *calcium* ar
ammonium to the chlorides. The *barium-salt* dried
calcium-salt dried at 100°, has a similar composition

Cupric mucate, $C^6H^8Cu''O^8.H^2O$ (at 100°), is a

Ferrous mucate, $C^6H^8Fe''O^8.2H^2O$ (at 100°), i
alkaline mucates from ferrous sulphate. It is perma
takes fire between 150° and 160°.

Mucates of Lead.—A *hexbasic* (?) *salt* is obta
of lead with mucate of ammonium. The *neutral s*
precipitating nitrate, chloride, or neutral acetate of
of ammonium. It gives off its water at 130°.

Mucates of Potassium.—The *neutral salt* fo
taining $2C^6H^8K^2O^8.H^2O$, which remain unaltered at
1 at. water at 150°. The salt dissolves in 8 pts. of
completely on cooling; it is insoluble in alcohol. T
ammonium-salt, forms transparent crystals, which
contain $C^6H^8KO^8.H^2O$.

Mucate of Silver, $C^6H^8Ag^2O^8$, is obtained by
mucic acid or a soluble mucate. It does not give o

Mucates of Sodium.—The *neutral salt* form
taining $2C^6H^8Na^2O^8.9H^2O$ which give off 8 at. wat
the last atom. The solution, if rapidly boiled

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$C^6Na^2O^8.H^2O$.—The *acid sodium-salt*, colourless shining prisms, con-$nO^8,7H^2O$: they give off their water at 100°.

ERS. *Amyl-mucic acid*, $C^6H^9(C^5H^{11})O^8$, is produced by the action on a mixture of amylic alcohol and mucic acid. It is crystallisable, ng water and in alcohol.

Ethyl. The *neutral* compound, $C^{16}H^{18}O^8 = C^6H^9(C^2H^5)^2O^8$, commonly *er*, is prepared by gently heating 1 pt. of mucic acid with 4 pts. of ll it turns black, then leaving it to cool, and adding 4 pts. of alcohol of 0·814. The mixture left to itself for 24 hours solidifies in a mass, shaken up with alcohol, thrown on a filter, washed with alcohol, and ated crystallisation from boiling alcohol.

yl crystallises in transparent four-sided prisms, terminated by a single ce. It is insipid at first, but leaves a bitter aftertaste. It melts at les in a crystalline mass at 135°. At a higher temperature it is re-ol, water, carbonic anhydride, acetic acid, carburetted hydrogen, pyro-charcoal. It is insoluble in ether, very soluble in boiling alcohol, very alcohol; very soluble also in boiling water, which deposits it in well-on cooling. The alkaline hydrates decompose it like other ethers: ts it into mucamide.

id or *Mucovinic acid*, $C^8H^{14}O^8 = C^6H^9(C^2H^5)O^8$. In the preparation of mucate, it sometimes happens that an aqueous solution of that com-ure, gives off all at once a very decided alcoholic odour, and yields by ubstance totally different in appearance from the neutral ether. It is ment with alcohol, which removes the neutral ether, and the residue is or three times from water. The product is pure when its solution is ed turbid by ammonia.

id is white, of asbestos-like aspect, the form of its crystals being that with rhombic base. It is moderately soluble in water, very slightly as a pure acid taste, and melts at 190°, with decomposition. The umes a vitreous aspect on cooling, but after a considerable time it n becomes opaque.

f ammonium, $C^6H^{12}(NH^4)O^8$, is very soluble, tasteless, and has a slight ts solution precipitates the salts of *lead*, *silver*, *copper*, *barium*, and slightly those of *calcium*, and forms no precipitate with salts of *zinc*, All the precipitates are soluble in acetic acid.

on of ethylmucic acid is boiled with oxide of silver, carbonic anhydride tion of the oxide is reduced, and a silver-compound is formed, which lightly heated.

Methyl, $C^8H^{14}O^8 = C^6H^9(CH^3)^2O^8$, is prepared like mucate of ethyl, from water or alcohol in laminæ, or in flattened six-sided prisms, olatile, and tasteless. It is very soluble in boiling water, very little in It decomposes at 163° without melting, and then changes to a black ells up, and gives off gases containing carbon.

AM. From experiments on the growth of these fungi (*Ascophora* in (Compt. rend. lvii. 771) concludes that they require for their normal elements of phosphate and sulphate of ammonium and of the carbo-m, magnesium and manganese, but that these elements are not all of em. If 20 grms. of the plant are produced in a given time in a liquid e substances above mentioned, then in the same time there will be bsence of manganese, 5 grms.; of sulphur, 2 grms.; of potassium and 1 grm.; and in the absence of phosphorus, only half a gramme of the ents in which these fungi were developed in a confined volume of air, nitrogen of the air was not essential to their growth. Similar results, the mineral constituents, have been obtained with plants of higher lle (Compt. rend. lvii. 270).

s. The gum of seeds, roots, &c. (See GUM, ii. 955.)

e name of one of the constituents of gluten (ii. 873); also of the chief imal mucus.

he normal secretion of mucous membranes. It is found in the respira-ary, digestive, &c. passages of animal bodies, mingled in certain situa-ic fluids furnished by special glands. It is very doubtful, however, retion ought to be considered as the same in all cases, whether in fact ing, mucus, modified by the addition of other matters from time to different secretion altogether for each membrane or organ. When ob-of approximate purity, mucus appears as an alkaline fluid of a very

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peculiarly glairy, ropy nature. Under the microscop granules, epithelial scales, varying in form and kin membrane from which the mucus is obtained, and which differ in no essential respect from pus-corp ments vary exceedingly in number in different speci absent.

Among the chemical constituents, the most import existing in the liquid in an undissolved condition. ropiness of the secretion.

Mucin is insoluble in water, and can be separated fr found on one occasion a mucus which was soluble in the filter. Heat produces no coagulation; on the c thereby effected. It may be precipitated by alcohol on the subsequent addition of water, will swell up i acetic acid and mineral acids precipitate it; conce alkalis, especially when dilute, also dissolve it. Fro be precipitated by alkalis added with caution. Fer precipitate either in alkaline or acid solutions, exce acid has been boiled. Tannic acid and basic acetat faintly alkaline solution; the neutral acetate and slight turbidity. Concentrated hot nitric acid col large quantity of water generally coagulates it, prob alkalis being thereby withdrawn. The difficulty of value of any elementary analysis. According to S carbon 52·4, hydrogen 7·0, nitrogen 12·8, oxygen 27 gives 4 per cent. ash, consisting chiefly of phosphate Mucin is found not only in ordinary mucus, but al various cysts, in the pathological product known as formed connective tissue of the umbilical cord and e

Besides mucin, mucus contains a very small q matters, and salts. Among the latter are sulphates a with earthy phosphates and especially alkaline chlorid parts of nasal mucus contain 93·37 water, 5·33 mucin is very often found in mucus, but may be regarded certain pathological states, various forms of albumi the surface of mucous membranes, as transudations times to change from mucous into muco-purulent or

It has been thought that mucus was generated by of the mucous membranes. The want of relationshi such epithelium scales and the amount of mucin in the presence of mucin in embryonal connective tissue mucin is not secreted by the mucous membrane as s surfaces out of some unknown antecedents, perhaps formed out of its peculiar antecedents.

The great use of mucus seems to be to lubricate th ferment-action has been largely attributed to it. T to be a chief cause of the change which urea speedil monium in exposed urine. The weak power of con by many mucus-bearing fluids, not containing saliva the mucus. This however is doubtful. The catal tainly does not reside in its mucus (Cohnheim). passages (sputa) during certain pathological states (are much increased.

MUDARIN. An extractive matter obtained fr *gigantea*, L. (A. Duncan. Fontenelle, Ann. C

MUDESIC ACID. A product of the oxidatio

MUDESOUS ACID. $C^{12}H^{10}O^8$ (?)—An organi alumina, forms the mineral called *Pigotite*, found co caverns in Cornwall. Pigotite is brown; yields a yell and alcohol; gives off 27 per cent. water in drying; s tures, giving off empyreumatic products, and lea The acid separated from the alumina is dark-brown, water, forms a deliquescent ammonium-salt, and giv salts. Nitric acid converts it into mudesic acid, to contain 2 at. oxygen more. Mudesous acid is s the remains of plants, its aqueous solution dissolvin

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percolated through the cavities. (Johnston, Handw. d. Chem. v. 406;

e from Wicklow in Ireland, probably identical with Pigotite, has been Apjohn (Jahresb. 1852, p. 903).

E BLUE. A blue dye, obtained by prolonged boiling of an alkaline ellac with aniline-red. (Schaffer and Gros-Renaud, Bull. Soc. In-house, xxxi. 238; Rép. Chim. app. iii. 273.)

'S GLASS, or *Hyalite*. A variety of OPAL (*q. v.*).

ITE. Syn. with SYLVANITE.

TE. Syn. with VIVIANITE.

LIER, or *Galvanometer* (see ELECTRICITY, ii. 443).

T. *Rubia Munjista.*—This plant, also called *East Indian madder*, is ltivated in India, its root being used as a dyestuff for producing colours se obtained from ordinary madder. The colouring matters contained in ver, by no means identical with those of common madder; in fact, as shown that it contains no alizarin, but that its colouring matter is a rpurin and an orange-dye, called munjistin (see the next article). The it produces are brighter than those of ordinary madder, but not so

ial power of munjeet was first examined by Runge in 1835, who reported ned about twice as much available colouring matter as ordinary madder; t experiments, both by German and by English dyers, have shown that as incorrect, and that the colouring power of munjeet is actually much of ordinary madder.

amount of colouring matter in munjeet is indeed very nearly the same madder. Stenhouse finds that the garancin from munjeet has about orial power of that made from the best madder, viz. Naples roots; these, only about 30 to 33 per cent. of garancin, whereas munjeet, according to nts of Mr. Higgin of Manchester, yields from 52 to 55 per cent.

rity of munjeet as a dyestuff results from its containing only the com-ble colouring matters purpurin and munjistin, only a small part of the available, while its presence in large quantity appears to be positively much so, indeed, that munjeet-garancin, freed by boiling water from the of the munjistin which it contains, yields much richer shades with ants than before. (Stenhouse, Proc. Roy. Soc. xiii. 148.)

TIN. $C^9H^6O^3$. (Stenhouse, Proc. Roy. Soc. xii. 633; xiii. 86, 145.)—olouring matter contained, together with purpurin, in munjeet or East r. It is nearly related in composition to purpurin, $C^9H^6O^3$, and alizarin, ring from the former by 1 at. and from the latter by 2 at. carbon. It njeet in considerable quantity, and may be extracted by the following

l of munjeet in fine powder is boiled for four or five hours with 2 pounds f aluminium and about 16 pounds of water, the operation being repeated imes; the red liquor thus obtained is strained through cloth filters while ; and the clear filtrate is saturated with hydrochloric acid, whereby a ecipitate is soon produced, which goes on increasing in quantity for hours if the liquid is left at rest. This precipitate is collected on cloth shed with cold water till the greater part of the acid is removed; then sed, and digested in a percolator with boiling sulphide of carbon, which rystallisable colouring principles of the munjeet, and leaves a considerable rk-coloured resinous matter. The excess of sulphide of carbon having by distillation, the bright-red extract, consisting chiefly of a mixture of l purpurin, is repeatedly treated with moderate quantities of boiling ered, the clear yellow filtrate consisting of a solution of munjistin, while e purpurin remains on the filter. The solution acidulated with hydro-lphuric acid deposits the munjistin in large yellow flocks, which are ed on a filter with cold water, then dried by pressure, and dissolved in of wine, slightly acidulated with hydrochloric acid, to remove any adher-As the munjistin does not subside from cold alcoholic solutions, even e largely diluted with water, about three-fourths of the spirit must be fter which the munjistin is deposited in large yellow scales. By two or sations from spirit, in this manner, it may be rendered perfectly pure.

nay also be extracted directly from munjeet by boiling with water, acidu-rk brownish-red filtrate with hydrochloric acid, and treating the precipi-; but the process above described yields a better product. The colouring

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matter of munjeet may also be extracted by boi
of aluminium is better adapted for the purpose,
lise, greatly impedes the filtration of the liquids.
acid (p. 749), is not applicable to munjeet.

Properties.—Munjistin crystallises from alcol
brilliancy. It is but moderately soluble in cold,
water, forming a bright-yellow solution, from whi
It dissolves to some extent in cold but more
precipitated therefrom by water. It dissolves,
carbonate of sodium; with *ammonia*, it forms a
brown; with *caustic soda*, it produces a rich crim

Munjistin, in some of its properties, bears consid
Schunck (madder-orange of Runge, p. 742); but
xii. 637), the two substances are perfectly distingu
in carbonate of sodium, when a small quantity
munjistin being red inclining to pinkish-orange, w
by the absorption-bands which are seen on exa
(see LIGHT, p. 638); both present a single minimu
rubiacin extends only from about D to F, that of
beyond D to some way beyond F. A further di
of the fluorescent light of the ethereal solutions
being orange-yellow, while that of munjistin is ye

Munjistin sublimes more readily than either
yellow scales consisting of the unaltered subst
nor that obtained by crystallisation from alcoho
weight at 100°. When carefully heated in a
on cooling. When strongly heated on platinum
away without residue.

Munjistin dissolves readily in cold *sulphuric a*
which may be heated nearly to boiling without b
acid, and on dilution with water, deposits th
rently unaltered. By digestion with moderately
alizarin and purpurin) into phthalic acid, C^8H
oxalic acid.

Bromine-water added to a strong aqueous s
pale-coloured flocculent precipitate, which when d
crystals, evidently a substitution-product.

Baryta-water forms a yellow precipitate with
copper forms a brown precipitate very slightly sol
added either to the aqueous or to the alcoholic so
precipitate, which when washed with alcohol and
average, 34·8 per cent. carbon, 1·9 hydrogen, and
the formula $Pb''O.5C^{16}H^{10}Pb''O^6$, analogous to tha
$Pb''O.5C^{18}H^{10}Pb''O^6$, described by Wolff and Stre

Both the aqueous and alcoholic solutions of m
form a beautiful lake of a bright orange-colour, al
withdrawn from solution. This lake is soluble i
ducing a fine crimson solution. Munjistin dyes cl
orange; with iron mordant it yields a brownish
mordant a pleasing deep orange. These colours
the application of bran and soap tolerably well.

When an ammoniacal solution of munjistin is
the munjistin is gradually but completely decomp
into a brown humus-like substance insoluble in an
non-crystalline colouring substance, analogous to p
manner from purpurin, *q. v.*), and capable of dyein
orange colour.

MUNTZ'S METAL. An alloy of copper a
for other purposes (see COPPER, ALLOYS OF, ii. 49

MURCHISONITE. A yellowish-grey o
Heavitree, near Exeter.

MUREXAN. *Dialurimide* (Laurent).—Disc
Phys. xi. 48), who called it *Purpuric acid:* furth
Ann. xix. 12), and by Liebig and Wöhler (A
formed by the decomposition of murexide by the
gen, or potash. It is obtained by adding sulphu

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urexide in water or potash: the crystalline precipitate is purified by cold sulphuric acid, and precipitating by water; or by dissolving it precipitating it by an acid. It is thus obtained as a heavy white ous like uramil, infusible, tasteless, and does not redden litmus. It air containing ammonia. It is almost insoluble in cold *water*, re- han 10,000 pts.: insoluble in alcohol, ether, dilute sulphuric, hydro- phoric acid, or in aqueous, acetic, tartaric, or citric acid. It is soluble *sulphuric* acid, and reprecipitated by water; also in aqueous *alkalis*, alising them, forming solutions which are colourless when air is ex-

decomposed by *dry distillation*, yielding cyanic acid and other products. l and decomposed by *chlorine-water*, without yielding cyanic acid. with strong *nitric acid* it is dissolved with effervescence, giving off rbonic anhydrides, and yielding on evaporation crystals of oxalate of dweiss). When heated with *sulphuric acid*, it evolves carbonic anhy- de nitrogen, and forms a brown solution, containing ammonia, and not y water. Its colourless solution in *ammonia* turns purple when ex- r, and on evaporation yields crystals of murexide:

$$\underset{\text{Murexan.}}{C^8H^7N^5O^6} + O + NH^3 = \underset{\text{Murexide.}}{C^8H^6N^6O^6} + H^2O.$$

ution is decolorised by exposure to oxygen-gas, oxalurate of ammonium

n circumstances murexan appears to combine with acids. It dissolves *nitric acid* without effervescence, and yields on evaporation small which appear to be nitrate of murexan. When dissolved in *oxalic acid* tle nitric acid, or when heated with strong nitric acid, it yields crystals , which, according to Kodweiss, are oxalate of murexan.

tion of murexan is very variously stated. The analyses of Liebig and of Kodweiss, yield very conflicting results: the former agrees toler- rmula $C^8H^7N^5O^6$, which is accordingly adopted by Liebig and Wöhler *him. org.* i. 1517) considers murexan as identical with dialuramide, view which is advocated by Beilstein (Ann. Ch. Pharm. cvii. 191), hose analyses murexan contains 29·54 per cent. nitrogen, which agrees 29·38, the calculated percentage in $C^8H^5N^5O^5$. Gmelin adopts the $^6O^6$, which gives percentages intermediate between the analyses, and mplest equations. Laurent (Compt. rend. xxxv. 629) adopts the same egards the compound as dialurimide—$N.C^8H^6N^4O^4.H$.

and W.		L. and W.	Kodweiss.		calc. Gmelin.	
6	33·33	33·32	36·58	C^8	96	35·69
4	3·70	3·72	2·22	H^7	7	2·60
3	25·93	25·72	28·45	N^5	70	26·02
0	37·04	37·24	32·75	O^6	96	35·69
8	100·00	100·00	100·00	$C^8H^7N^5O^6$	269	100·00

F. T. C.

DE. See PURPURATES.

EN. A product formed by the joint action of air and ammonia on and crystallising from warm water or alcohol in vermilion-coloured ms, two faces of which reflect light with gold-yellow colour. The solu- mpound resembles that of murexide, excepting that it is decolorised ng turned blue by potash, also by evaporation. When dried at 100°, lysis numbers agreeing approximately with the formula $C^{32}H^{22}N^{10}O^{16}$. J. p. Chem. li. 398; Jahresb. 1850, p. 434.)

TE. Syn. with ANHYDRITE (i. 295).

IC ACID. The old name of chlorhydric or hydrochloric acid (i. 390).

NITE. A variety of orthite (*q. v.*) from Baden near Marienberg in

he ripe fruit of the Banana (*Musa paradisiaca*), grown in Bengal, con- g to Corenwinder (Compt. rend. lvii. 781), 73·9 per cent. water, 4·82 ellulose, 0·63 fats, 19·66 cane-sugar and inverted sugar (together with pectose, and traces of starch), 0·06 phosphoric anhydride, and 0·73 on, chlorine, &c. The ash of the husk of the ripe fruit was found to carbonate of potassium, 6·58 carbonate of sodium, 25·18 chloride of

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potassium, 5·66 alkaline phosphates (with a little silica, earthy phosphates, &c. (= 100).

In the milky juice of the flower-stem of the sam xliii. 269) found 25·27 per cent. potash, 9·52 soda alumina, with a trace of ferric oxide, 6·30 chlor phosphoric anhydride, 0·81 silica, and 34·17 carb bases).

MUSCLE. See MUSCULAR TISSUE.

MUSCOVITE. Potash-mica. (See MICA, p.

MUSCULAR TISSUE. A. *Striated muscle animal life,—Muscles taking part in energetic move* mitive bundles of fibres bound together with fat affording gelatin, not proper to muscular tissue it as a tube consisting of—1. A sheath or *sarcolemm* cally, elastic tissue;—2. *Nuclei*, whose exact chemic *muscle-substance* or *fluid* (semifluid) contents of th striæ;—4. *Granules*, &c., mostly fatty;—5. Term

The living fibre is contractile, and very extensibl its substance is transparent. When the nutrition is lost, and the condition known as *rigor mortis* c is shorter and thicker than during life, and has peculiar rigidity thus brought about passes away a

The rapidity with which rigor mortis appears somatic death, depends upon a variety of circu rigidity may be instantaneously brought about by a temperature of 40° (for cold-blooded animal birds; Kühne, *Myolog. Untersuch.*), or by injecti stances, such as chloroform (Küssmaul, Virchow has been considered as a species of contraction,- muscle," or the natural condition into which a mu by life (Radcliffe). It seems more probable, h is due to a spontaneous coagulation of the muscle-

The reaction of the living fibre, when freed as f or amphichromatic. After death, with the onset continues so until changed by ammoniacal compou acid is probably formed first in the interior of th muscle remains neutral the longest; and if it be oxygen must be furnished by the muscle-substance oxygen is wholly unnecessary. The reaction cannot of potassium, for the mark on litmus is permanent It is generally supposed to be due to lactic (sarc cially produced by a temperature of 40° (frog becomes acid. When muscles, however, are plung immediately, with a distinctly alkaline reaction neutral, with a tendency to acidity or alkalinity. due to any destruction of a temporarily formed ac the alkali set free by the coagulation of the alb become acid remain so, even when immersed for s muscles coagulated by being plunged into alcohol r fore, to be no causal connection between rigor mort (Du Bois-Reymond, *Moleschott. Untersuch.*, 186

Though rigor mortis may be considered as a through the vessels of a rigid limb will remove (Stannius, Brown-Sequard). Kühne, how revival can take place when rigidity and acidit nevertheless may be removed by an injection of chl (*Untersuch. über Protoplasma*) the interesting obs appears at the same time; and Preyer (Central-b states that if a blood-injection follow the chlorid may be restored.

The *muscle-substance*, whose fluidity is indicate contractions, by its movement towards the negat electric current (Kühne), and by the behaviour sarcolemma, was supposed by Brücke, and has bee tain a body whose spontaneous coagulation brings dead fibre. If a frog be opened, a 1 per cent. solution

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until all blood is removed, the muscles then rapidly chopped up and pressure, a liquid will be obtained, which in a short time sets into a hile the remaining fragments of muscle show a great lack of rigidity. ment, however, much of the muscle-substance will, through the treat- rigid before the liquid can be expressed from it. In order to obtain gulation sufficient to justify the idea that the rigidity is due to a muscle-substance itself, and not of any lymph or plasma bathing the d from blood by the injection of the (1 per cent.) solution of chloride of minutely divided, mixed with four times their volume of snow contain- hloride of sodium, and the mass pulverised as far as possible. At $-3°$ become sufficiently liquid to be filtered through linen; at 0° it may through filtering paper. The filtrate then appears as a slightly opa- h, exposed to ordinary temperature, will speedily set into a coagulum containing vessel may be turned over without any fear of spilling the temperature of 40° coagulation takes place instantaneously. On ulum contracts, after the fashion of a blood-clot, but shows a great roduction of flocks and flakes, and leaves the surrounding liquid highly pting the phraseology used in speaking of blood, the fluid parts of scribed as forming a muscle-plasma, which separates into the muscle- erum.

ulation may fairly be supposed to be, like that of blood, the union compound of two soluble factors. Kühne found that one of the coagulation, viz. globulin, increased and hastened the coagulation of The cause or determining circumstance of the coagulation is un-

ame given by Kühne to the muscle-clot) is, when thoroughly washed, l, forms when wet a white mass of little transparency, when dry a tance. It gives the usual protein reactions, and contains sulphur. water, alcohol, and ether, exceedingly soluble in very dilute acids, n solutions of neutral salts of all degrees of concentration. In a ion of chloride of sodium it is especially soluble, and may by this d from muscles already coagulated. (Hence in brine there is always siderable quantity of it.) If such a solution in chloride of sodium be op to distilled water, the myosin is precipitated in flakes or lumps, le vesicles. The precipitate so formed is unaltered myosin, and ved in the chloride of sodium solution. The precipitate obtained, utralisation of dilute acid or alkaline solutions of myosin is no longer anged in character, is no longer soluble in the chloride of sodium bits the reactions of syntonin.

m (that is, muscle-plasma minus muscle-clot or myosin) Kühne re- hree forms of albumin:—

whose coagulation depends in great part on the degree of acidity serum. If abundance of acid be present, coagulation will occur at a w as 30°. In this body Kühne recognises the mixture of potassic odic phosphate described by Rollett.

coagulating at 45°.

ntity of albumin coagulating at 75°. There are also in untouched s coagulating at 90°. The first form had been previously recognised nle u. Meissner's Bericht, 1859, p. 471), and was regarded by him as rigor mortis. And even though the formation of myosin, which is t of the formation of acid, be considered as the chief part of rigor bsequent coagulation caused or favoured by the presence of the acid increase that condition.

earches of Kühne, muscle was considered to consist of a small in and of a large quantity of syntonin. Myosin is not the same n. Kühne contends that syntonin does not exist as such in the un- ut is an artificial product due to the action of the dilute acid on albuminoid bodies. He attributes the rapidity of the solution of the to the conjoined action of pepsin (the presence of which in muscles y Brücke), and affirms that a formation of syntonin always precedes nes in every digestion of albumin. v. Wittich (Königsberg. med. so adopts the same view (see SYNTONIN). Hence muscle-fibrin or by Liebig's method would be regarded as consisting of myosin and lating at 30°; muscle-juice as a mixture of the other forms of albumin. ingular in being an involuntary muscle, and yet being composed of It is remarkable for containing inosite, which is not found in other coholic extract exhibits that excess over the watery extract which is

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characteristic of muscles actively exercised. Its
striated muscles. (Du Bois-Reymond.)

B. *Non-striated, smooth muscles,—Involuntar*
Muscles taking part in slow movements,—Contra
spindle-shaped cells, or riband-like fibres, mark
bound together with connective tissue, bloodvessel
with in the analysis of this variety, since the fi
isolated masses, and are much mixed up with ot
quantity and often mixed with other fluids. Leh
the muscular coat of the pig's stomach distinctly
feebly acid, that of *Tunica Dartos* neutral (*Lehrb*
however, found the muscles of the gizzard of fow
after death, as also the muscular coat of intestine
(Ann. Ch. Pharm. lxxi. p. 277) had previous
Siegmund (Verh. phys. med. Gesellsch. Wurzb
muscles, acetic, formic, and lactic acids. From
rently identical with the syntonin of striated m
former exhibit rigor mortis, they also probably
coagulating spontaneously. Schultze (*op. cit.*
the middle coat of arteries a large quantity (7 t
substance which he believed to be casein. Crea
proportion of potash to soda is much less th
muscles of the stomach, 42 : 58 in the middle co
imply a great mixture of blood-serum.

C. *Muscles of Invertebrata.*—These are
ata); in others, non-striated (e. g. *Mollusca*),
striated than with the non-striated variety of ve
They probably agree in their main chemical fea
(Centralblatt für med. Wissensch. 1863, p. 437)
or faintly alkaline when living, but becoming ac
also obtained a spontaneous coagulation of th
muscles he found the foot neutral, the adductors
ously coagulating juice.
Valenciennes and Frémy (Ann. Ch. Phys
replace the acid phosphate of potassium in the m
ascertained the absence of creatine and creatinin

D. *Protoplasma,—Sarcode.*—The bodies
in great part of a semifluid substance, capabl
matter is also found in vegetable cells and in the
connective tissue). From the researches of Sch
(*op. cit.*) it appears that this protoplasm is c
and exhibits other reactions which bespeak
substance.

Metamorphosis of Muscular Tissue.—
the living muscle, though most imperfectly know
of oxidation. Living muscles consume oxygen a
Müller's Archiv. 1850, p. 409; Matteucci, Com
Physiol. Heilk. N.F. i. p. 285); the excretion
muscle is placed in hydrogen-gas. Products
are always present in muscle—creatine, creatinine,
taurine, leucine, &c.
On comparing the chemical composition of m
work, it is found that by the act of contraction,
creased and those soluble in water diminished (H
and the oxygen consumed are increased, the
being at the same time also increased (Matte
Zeitsch. nat. Med. xvii. p. 106); the substance
(Cl. Bernard, Med. Times and Gaz. 1861, ii.
at the expense of creatine. Heidenhain (*Me*
thätigkeit) finds the amount of acid produced t
energy liberated during the contraction (Sarc
A muscle when tetanised becomes acid from a
Reymond, *op. cit.*). It is uncertain wheth
or a permanent constituent temporarily increase
natur. Wissensch. Zeitsch. ii. p. 65) finds no lac

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er, 1861, p. 295), however, finds it. With regard to creatine, *it.*) believes that it is formed at the expense of creatinine, while ch. analyt. Chem. 1863, p. 22) regards creatinine as an artificial natural constituent of muscle.

he carbo-hydrates in muscle is a very uncertain one. In the muscles ecogen is found in abundance (Bernard, Journal de Physiolog. ii. *id.* p. 333); in the muscles of adults, occasionally. (McDonnell, 536.)

hich exists in the muscles of the heart, Meissner (Henle u. Meissner, ound in the muscles of the system, a fermentable sugar (not arising presents, as he thinks, some differences from hepatic sugar, and is scular metamorphosis. Harley (Brit. For. Med. Chir. Review, 1857) as. Med. No. 23), however, find reason to believe in the destruction temic capillaries (and therefore in part at least in the muscles).

steris paribus, increases rigor mortis, it might be inferred that one at of myosin was developed during muscular metamorphosis. In the views, the nitrogenous muscle-substance, the 'plastic' element, is by its conversion the force of muscular movements. Others (Traube) at the hydrocarbons and carbo-hydrates (of blood and muscle) are he main source of power. M. F.

ARK. This bark, used in Abyssinia as an anthelmintic, contains, (J. Pharm. [3] xlii. 176), a sharp-tasting colloïdal substance called in water and in alcohol, insoluble in ether.

Cobalt-pyrites from Müsen, near Siegen, in Prussia (i. 1050).

Moschus.—An odoriferous resinous substance contained in a bag he male musk-deer, a small animal inhabiting Tonquin and Thibet. mmerce in brownish clots, often mixed with hair, sand, fat, and resins ste, a persistent odour, is very inflammable, and partially soluble in ol. According to an analysis by Geiger and Reimann, it contains arts fat, 4·0 cholesterin, 5·0 bitter resin, 7·5 alcoholic extract (lactic lts soluble in water (potash and ammonia, combined with a peculiar 5·5 ammonia combined with lactic acid and water, and 0·4 sand. ny, *Traité*, vi. 240. See also *Ure's Dict. of Arts, &c.*, iii. 211.)

ELLS. See Shells.

yn. with diopside or white augite (see Augite, i. 475).

. Syn. with Parisite.

uice of the grape, expressed for making wine, but not yet fermented same term is also applied to the freshly-expressed juice of apple. s to conversion into cider and perry by fermentation.

The seeds of black and white mustard (*Sinapis nigra* and *S. alba*), ifted, furnish the *flour of mustard* used as a condiment.

ite mustard yields an ash containing 25·78 per cent. potash, 0·33 5·90 magnesia, 0·39 ferric oxide, 2·19 sulphuric anhydride, 1·31 horic anhydride, and a trace of chloride of sodium: 100 parts of elded 4·07, and 100 parts of the dried seeds 4·45 parts ash; 100 ried seeds were found to contain 8·50 parts moisture and 1·212 Way and Ogston, Jahresb. 1850, Table B, p. 660.)

OILS OF. *a. Fixed Oils.* White mustard-seed yields by pressure . of a yellow nearly inodorous oil, which has a specific gravity of l is not solidified by cold. When saponified with soda, it yields ap which is perfectly soluble in water, and when decomposed by yields a solid crystalline acid, called erucic acid (ii. 501), and an arly the composition of oleic acid.

eed yields 18 per cent. of an oil similar to the preceding, having a ut solidifying at temperatures below 0°. According to Darby (Ann. , it yields by saponification, stearic acid, erucic acid, and an oily acid.

When the flour of black mustard, after being freed by pressure is moistened with water, left to itself for several hours, and then r, it yields a very pungent volatile oil, having the properties and

hocyanate of allyl, $C^4H^5NS = \left.\begin{matrix}CN\\C^3H^5\end{matrix}\right\}S$. It is especially distin-

haviour with ammonia, with which it immediately unites, forming iosinnamine or sulphocyanate of allyl-ammonium ee Sulphocyanic Ethers).

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This volatile oil does not pre-exist in the s
from myronic acid (p. 1073) contained in the
a peculiar ferment called myrosin (p. 1075),
it is not produced unless the mustard-flour
previous to distillation. Its formation is like
high temperature, or by heating it with alco
myrosin is rendered inactive.

The quantity of volatile oil obtained from bl
only 0·2 per cent. according to Boutron and
Aschoff, and 0·5 per cent. according to Witt
White mustard does not yield any volatile oil,

MYCLOCLONE. Syn. with CERBEROTE

MYCODERMA. A generic name of th
according to Pasteur and others, are essentia
fermentation. See Pasteur (Bull. Soc. Chi
p. 726; Compt. rend. lv. 28; Jahresb. 1862, p.
VINEGAR, and WINE, in this Dictionary.

MYCOMELIC ACID. *Alloxenide* (L
$C^4H^4N^4O^2.\frac{1}{2}H^2O$. (Liebig and Wöhler,
aqueous alloxan is heated gently with ammo
deposits a yellow transparent jelly of mycomel
from the hot aqueous solution of which salt sul
When freshly precipitated, it is transparent
dried it is a loose yellow powder, which redde
water, more soluble in hot; insoluble in alcoh
out forming crystallisable salts: its solution in
evolution of ammonia. It decomposes alkalin

It is a monobasic acid. The only mycomel
the silver-salt, which is precipitated in yellow
to nitrate of silver.

According to Liebig and Wöhler's analy
when dried at 100°. Gerhardt (*Traité*, i.
$+ 2NH^3 - 2H^2O$); Laurent (Compt. rend.
acid $+ 2NH^3 - 3H^2O$).

According to Hlasiwetz (Ann. Ch. Phar
when uric acid is heated with water to 180–19

MYCOSE or **TREHALOSE.** $C^{12}H^{22}O^{11}$.
i. 173), observed in ergot of rye a peculiar ki
vestigated in 1857 by Mitscherlich (*ibid.* c
Berthelot in the same year (Ann. Ch. Phys
from trehala-manna, the produce of a species o
which he called trehalose, and at first rega
further examination he was led to infer that
Handbook, xv. 299–301.)

Mycose is obtained from ergot of rye by p
fungus with basic acetate of lead, removing the
evaporating to a syrup, and leaving the liqui
from trehala-manna by exhaustion with boilin

Mycose (trehalose) forms shining rhombic
which melt when quickly heated to 109°; but
even below 100°. It has a strongly sacchari
boiling *alcohol*, but is insoluble in *ether*. T
For trehalose, Berthelot found $[\alpha] = + 199°$
tory power of mycose is, according to Mitscher

By several hours boiling with dilute *sulp*
glucose. With strong *nitric acid* it forms a de
dilute nitric acid it yields oxalic acid. In co
perfectly into alcoholic fermentation. It is n
does not reduce cuprous oxide from alkaline c
butyric acid, it yields saccharides, not disti
in like manner from dextro-glucose (ii. 854, 85

MYELIN. A kind of kaolin, found at Ro
and containing, according to Kersten, 37·62 pe
nesia, 0·63 manganic oxide, and a trace of ferr

The name myelin is also applied by Kir

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culiar fatty substance obtained by evaporating the alcoholic extract
k of egg, brain-substance, crystalline lenses, and other animal tissues,
which is especially characterised by shooting out into peculiar spiral
hen immersed in water or in a solution of sugar—is found, according
ne of the lower animals (*e.g.* in *Helix Pomatia*, p. 140), and likewise
oung chlorophyll, in some flower-stalks, in certain seeds, especially
s accompanied by cholesterin. (Jahresb. 1862, p. 507.)

LLOW. *Myrtle-wax.*—A solid fat, obtained by pressing the
erifera (or *M. cordifolia*, John) with water. It is pale-green, trans-
friable in the cold; of splintery fracture, less extensible when warm
as an aromatic taste and odour. Specific gravity 1·005 (Moore,
xxiii. 113). Melts at 47° to 49° (Moore). When purified by
ling water and cold alcohol, it melts at 47·5°, and contains 74·03 per
and 13·70 O (Lewy, Ann. Ch. Phys. [3] xiii. 448). It contains
palmitic and a small quantity of myristic acid, for the most part in
to a smaller extent combined with glycerin; no oleic nor any volatile

0 pts. of hot alcohol, a portion (palmitin, according to Moore) re-
undissolved, and on cooling ⅔ separates out; the solution, formed
olidifies on cooling, and when perfectly cold is no longer precipi-
t is nearly insoluble in cold ether, but dissolves in 4 pts. of boiling
as it cools, depositing the greater part of the tallow without colour,
a fine green colour. Cold oil of turpentine softens, and hot oil of
s $\frac{1}{10}$ pt. of it, the solution on cooling depositing white opaque granules.
es easily in fixed oils.

(Brodie, Ann. Ch. Pharm. lxxi. 244).—The portion of beeswax
in boiling alcohol. It is prepared by exhausting beeswax with
the alcoholic liquid no longer gives a precipitate with acetate of lead.
obtained melts at 64°, and has a faint waxy odour. It consists
te of myricyl, $C^{60}H^{62}O^2 = C^{30}H^{31}(C^{30}H^{61})O^2$; and by dissolving it
ng the solution to evaporate, the palmitate of myricyl is obtained in
stals, melting at 71·5° or 72°, and easily saponified by potash,
olic solution, yielding palmitic acid and hydrate of myricyl. Crude
saponification, the same products, together with small quantities of
a neutral substance resembling hydrate of ceryl (i. 838). Crude
ry distillation a number of fatty acids, of which palmitic acid forms
together with solid and liquid hydrocarbons. (See Melene, p. 868).

YDRATE OF. *Melissic alcohol, Melissin*, $C^{60}H^{62}O = \left.\begin{matrix} C^{60}H^{61}O \\ H \end{matrix}\right\} O$.
ans. 1848; Ann. Ch. Pharm. lxxi. 144.)—This compound, which is
alcohol of the series $C^nH^{2n+2}O$, is obtained by the action of melting
in. On dissolving the product in water, precipitating the milky
ains the alcohol in suspension, with chloride of barium, exhausting
h ether, and leaving the solution to evaporate, hydrate of myricyl is
y be purified by crystallising it from ether, till it melts at 85°. A
ication also is to exhaust the precipitate with boiling alcohol, and
nce which is deposited from the alcohol in rock-oil or rectified, coal-

or then retains in solution a small quantity of another substance
° and gives by analysis the same numbers as hydrate of myricyl.
to be an alcohol of similar constitution. When treated with potash-
cid containing $C^{30}H^{29}O^4$. (?)
cyl is a crystalline substance having a silky lustre. It contains, ac-
's analysis, 82·02—82·77 per cent. C, and 13·97—14·25 H. (calc.
and 3·66 O.)
d to *dry distillation* it partly sublimes unaltered, and is partly
and a solid hydrocarbon (melene, p. 868). Heated with *potash*-
drogen, and is converted into melissate of potassium:

$$C^{60}H^{62}O + KHO = C^{30}H^{29}KO^2 + H^4.$$

phuric acid it forms acid sulphate of myricyl. Chlorine converts it
ly (*chloromelal*), which gives by analysis numbers corresponding to
$^{30}Cl^{14\cdot4}O$.

ACID. $C^{14}H^{28}O^2 = \left.\begin{matrix} C^{14}H^{27} \\ H \end{matrix}\right\} O$. (Playfair, Phil. Mag. [3] xviii.
harm. xxxvii. 153.—Heintz, Pogg. Ann. lxxxvii. 267; xc. 137;
—*Summary of the Results*, J. pr. Chem. lxvi. 1.—Uricoechea, Ann.

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Ch. Pharm. xc. 369.—Schlippe, *ibid.* cv. 1.—Ou
and 367.—Gm. xvi. 209).

This acid was discovered by Playfair, and obt
myristin (myristate of glyceryl), in nutmeg-butt
coechea), in dika-bread (ii. 330), amounting to
contained therein; also in small quantity, togeth
cocoanut-oil (Gorgeu, Ann. Ch. Phârm. lxvi. 314
croton-oil (Schlippe); and in combination wit
spermaceti (Heintz). According to Heintz a
artificially by heating ethal with potash-lime; but i
due to the presence of methal or myristic alcohol (

Preparation. α. From *Spermaceti.*—When the
ethal, by the saponification of spermaceti, as des
are dissolved in alcohol, a mixture of palmitic and
while a portion of both these, and the whole of the
solution. By fractional precipitation with acetate
of excess of ammonia) the alcoholic solution is aga
palmitic, and a portion of the myristic acid being
while the lauric acid and the rest of the myristic

Treatment of the precipitated magnesium-salts.—
fatty acids by boiling them with dilute hydrochl
portion of acid so obtained is determined; and t
the same temperature, and do not differ essentia
mixed together. When, now, the mixture of a
alcohol, and the melting-point of the crystallis
several successive crops of crystals are obtained f
considered pure:—1. When their melting-point re
tallisation; 2. When they solidify, on cooling, in
fractional precipitation of their alcoholic solutions
having one and the same melting-point are obta
same acid show also, when pure, the same melting
when separate. Sometimes, especially in the prep
sary to subject the single crystallisations anew
repeat the above treatment and examination of
(Heintz, Pogg. Ann. xcii. 429.)

In this way Heintz obtained, by the first precip
nineteen magnesium-salts, from each of which he
together the *first six portions of acid*, the melting-
45°, allowed them to separate from alcohol, and r
times: but even the last crystallisation proved to b
acids, and in no case was a pure acid obtained.
from the first nine crystallisations in seven porti
succeeded in obtaining, from the first, second, and
times repeated crystallisation, pure, or nearly pure,
fifth portions, yielded by seven times repeated, th
repeated crystallisation, myristic acid melting
signs of purity. Of the remaining acids of the ni
and *eighth portions* did not yield a pure acid by
recognised as mixtures of palmitic and myristic
mixed together. The part which first separated
yield a pure acid on repeated crystallisation; after
therefore, a portion of the acids present was prec
acetate of barium. The filtrate mixed with wat
melting at 53·8°, which yielded, on recrystallisation
separated from the *eighteenth* and *nineteenth portion*
to be also myristic acid. The quantity of myr
is but small.

β. From *common butter.*—The mixture of acids
decomposing the soap, is freed from volatile acid
oleic acid by treating the lead-salt with ether, af
allowed to crystallise. After removing by recrystal
as can be obtained with a melting-point of 56° or
acids), the collected alcoholic mother-liquors are su
with acetate of magnesium; the myristic acid is th
the precipitate, and may be obtained therefrom
necessary, the substances at first precipitable by ac

γ. The acids obtained by the saponification of *dik*

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from alcohol, while a second portion of the acid, together with lauric acid, ution. This latter portion may be recovered by precipitating the solution ts with acetate of magnesium, separating the magnesia, and crystallising ortions of acid until the melting point rises to 53·8°. (Oudemanns.)

yristin. Playfair saponifies the myristin of nutmeg-butter with strong ; washes the soap repeatedly with solution of common salt; and after- oses the hot aqueous solution with hydrochloric acid. The acid, which colourless oil, solidifying on cooling, when freed from all traces of hy- d by washing with water, yields, on repeated crystallisation from alcohol, istic acid, having a melting-point of 49·8° (impure, therefore, and con- h an acid containing a smaller proportion of carbon). (Heintz.)

ifying *otoba fat*, acids are obtained, from an alcoholic solution of which gnesium precipitates only, or chiefly, myristic acid, while oleic acid ntion. (Uricoechea.)

—Myristic acid forms white, shining, crystalline laminæ, resembling It has an acid reaction, is perfectly insoluble in *water*, but dissolves *alcohol*, crystallising on cooling; it is perfectly insoluble in *ether*. It , and solidifies on cooling in crystalline scales. (Heintz.)

Melting-points of Mixtures of Lauric and Myristic Acids, according to Heintz.

e of— Lauric acid.	Melts at	Solidifies at	Mode of solidifying.
10	51·8°	47·3°	Crystalline scales.
20	49·6	44·5	Very fine crystals, not distinguishable as either needles or scales.
30	43·7	39	Ditto ditto
40	43	39	Uncrystallised, with isolated lustrous spots.
50	37·4	35·7	Large crystalline laminæ.
60	36·7	33·5	Uncrystallised, with isolated lustrous spots.
70	35·1	32·3	Uncrystallised, wavy.
80	38·5	33	Ditto ditto
90	41·3	36	Crystalline needles.

rved that when the lauric acid amounts to 40 per cent. or more, the melt- he mixture lies below that of either constituent. This is generally the res of fatty acids, when the quantity of the more fusible constituent in portion of the whole.

ons.—1. Myristic acid subjected to *dry distillation*, is partly decomposed tilised unaltered.—2. On boiling with *nitric acid*, a part is converted into ts, with evolution of red vapours, the remaining undissolved portion unchanged myristic acid (Playfair).—3. By the dry distillation of the yristone is produced (Overbeck).—4. A mixture of myristate and formate lds a repulsive-smelling oil, which deposits a small quantity of a solid last, purified by recrystallisation, forms small, white, crystalline scales larger proportion of carbon and hydrogen than would be contained in yde (Limpricht, Ann. Ch. Pharm. xcvii. 371).—5. Myristate of potas- ith *oxychloride of phosphorus*, yields myristic anhydride; with *chloride* zo-myristic anhydride. (Chiozza and Malerba.)

.—Myristic acid is monobasic, the general formula of the myristates O^4 or $C^{28}H^{26}M''O^4$, according as they contain mono- or di-atomic metals. of the alkali-metals are not decomposed by water (like the stearates) of acid salts. (Playfair.)

of Barium, $C^{28}H^{26}Ba''O^4$, is obtained from chloride of barium and otassium by double decomposition (Playfair). Heintz precipitates hot tic acid with a hot concentrated aqueous solution of acetate of barium, and cipitate with weak alcohol and hot water. Oudemanns precipitates the with chloride of barium. It is a very light crystalline powder, consisting oscopic nacreous laminæ. It is very slightly soluble in water and composes before melting.

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Myristate of Copper, $C^{28}H^{54}Cu''O^4$, is obta
loose, bluish-green powder, consisting of micro
coloured when heated above 100°, and cakes tog

Myristate of Lead, $C^{28}H^{54}Pb''O^4$, obtaine
amorphous powder which melts at 100°—120°, and
amorphous mass (Heintz). An *aceto-myrista*
is obtained as a heavy white powder, insoluble in
days with basic acetate of lead.

Myristate of Magnesium. $C^{28}H^{54}Mg''O^4$
and sal-ammoniac have been added, is precipitat
precipitate washed with water. Very light powd
becoming transparent at 140°, semi-fluid at 150°,
ture. The salt dried in the air contains 9·54 pe
H^2O). (Heintz.)

Myristate of Potassium. $C^{14}H^{27}KO^2$.—
trated aqueous carbonate of potassium; the pre
myristate of potassium extracted by absolute
soap, easily soluble in water and in alcohol, inso

Myristate of Silver, $C^{14}H^{27}AgO^2$, is obta
the sodium-salt and nitrate of silver, as a whi
slightly grey when exposed to light. It deco
(Heintz); dissolves in aqueous ammonia, and
large transparent crystals. (Playfair.)

Myristate of Sodium, $C^{14}H^{27}NaO^2$.—A b
sodium, quite free from sulphate and chloride, is
myristic acid, and the mixture is evaporated co
The residue is then extracted with boiling absol
The filtrate, which solidifies to a jelly on coolin
with water in the proportion of one-eighth of the
liquor is formed which takes up any foreign salt
salt is collected on linen and strongly pressed. (

MYRISTIC ALCOHOL. *Methal.* $C^{14}H^{3}$
posed to exist together with cetylic alcohol or et
series, in commercial spermaceti. When this s
palmitic, myristic, and lauric acids are obtained,
the latter is recrystallised from alcohol, pure etha
whilst the homologous compounds, *stethal* $C^{28}H^{5}$
remain in smaller quantity in the mother-liquor
from these mother-liquors (after the removal of
treatment with alcoholic potash and addition
potash-lime to 275°—280°, as long as hydrogen
myristic, and lauric acids. (Heintz, Ann. Ch.
Chem. lxvi. 19.)

MYRISTIC ANHYDRIDE. $C^{28}H^{54}O^{3}$
Malerba, *Gerh. Traité*, ii. 789.)—Obtained, lik
by the action of oxychloride of phosphorus on my
substance, which scarcely exhibits any crystallin
degress lower than that of myristic acid.
vapours having a disagreeable odour. It is but slow

MYRISTIC ETHERS. *a. Myristate o*
drochloric acid gas is passed into a hot solution o
the oil which separates on cooling is washed repe
solved in a small quantity of warm alcohol. The
after being separated from the alcohol and cooled,
crystals, from which the mother-liquor is to b
gravity of myristic ether is 0·864 (Playfair).
in ether.

β. Myristate of Glyceryl. Myricin. C^{45}
loc. cit.)—When nutmegs, after exposure to the
between hot iron plates, a fatty matter called nut
of an oily liquid, which has not been examined,
myristin. To separate the latter, the crude fat

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ristin, which floats on the surface of the liquid, is dissolved in boiling
ystals which separate on cooling are pressed between bibulous paper,
and submitted to alternate pressure and crystallisation till they melt
. (Playfair.)

prepared is crystalline, and has a silky lustre. It is soluble in all
iling ether, less soluble in boiling alcohol, insoluble in water. By
yields acrolein and a fatty acid. Digested in the water-bath with a
acetate of lead, it yields insoluble myristate of lead and a solution of

ins, according to Playfair's analysis, 76·51—74·15 per cent. C, and
numbers agreeing nearly with the formula $C^{110}H^{206}O^{12}$ (calc. 74·51 C,
·27 O), according to which myristin contains the elements of 4 at.
1 at. glycerin *minus* 7 at. water:

$$C^{110}H^{206}O^{12} = 8C^{14}H^{28}O^{2} + 2C^{3}H^{8}O^{3} - 7H^{2}O.$$

on is, however, not very probable, no corresponding example of it
g glycerides of well-known constitution. The above formula $C^{45}H^{86}O^{6}$,
ltzien, requiring 74·82 per cent. carbon and 11·91 hydrogen, agrees
the results of Playfair's analyses.

of the fruit of *Myristica officinalis*, and that of *M. sebifera*, possess
to those of nutmeg-butter.

a. A genus of plants, including the nutmeg (*Myristica moschata*),
s of several species of which yield solid fats or waxes. *Bichuhyba-*
from *Myristica Bicuhyba*; *Ocaba-wax* from *M. Ocaba* or *M. sebifera*,
obite, from *M. Otoba* (see WAX). The seeds and arillus (mace) of *M.*
eld volatile oils by distillation with water. (See MACE, p. 740; and

IN. The camphor or stearoptene of volatile oil of nutmeg. (See

. See MYRISTIC ETHERS.

BENZOIC ANHYDRIDE. *Myristate of Benzoyl* or *Benzoate of*
$^{28}O^{3}$ = $C^{14}H^{27}O.C^{7}H^{5}O.O$. (Chiozza and Malerba, *loc. cit.*)—
action of chloride of benzoyl on myristate of potassium. Crystal-
having a silky lustre and agreeable odour. Melts at 38°; solidifies
y soluble in ether.

E. $C^{27}H^{54}O$ = $C^{14}H^{27}O.C^{13}H^{27}$. (Overbeck, Pogg. Ann. lxxxvi.
t obtained by distilling myristate of calcium by small portions and at
easing temperature. It is purified by repeated crystallisation from
nd decolorised if necessary by animal charcoal.

ns colourless nacreous scales, inodorous and tasteless; they become
ion. It melts at 75°, and solidifies in a radiated mass on cooling. It
81·81 per cent. C, and 14·07—13·95 H, whence Overbeck deduces the
(calc. 81·96 C, 13·65 H). Gerhardt suggested the formula above given
·7 H, 4·07 O), representing the compounds as the acetone of myristic

, HYDRIDE OF. $C^{14}H^{30}$ = $C^{14}H^{29}.H$.—This alcoholic hydride,
lled hydride of tetradecatyl, is contained, together with many
the same series, in American petroleum. It boils between 236° and
OLEUM and TETRADECATYL.)

ACID. $C^{10}H^{19}NS^{2}O^{10}$ (from *μύρον*, a sweet-smelling ointment).—An
the form of a potassium-salt in the seed of black mustard, and giving
ion with myrosin, to the production of the volatile oil of black
yanate of allyl). It was discovered by Bussy (J. Pharm. xvi. 39); and
ich was afterwards called in question by Thielau (Vierteljahrsschr.
161), has been fully confirmed by the experiments of Ludwig
eitschr. Chem. Pharm. 1860, pp. 430 and 577) and of Will and
Ch. Pharm. cxxv. 257; Jahresb. 1863, p. 495). According to
resb. 1849, p. 436), myronate of potassium likewise exists in horse-

the Potassium-salt.—Two pounds of black mustard-seed pulverised
m fixed oil by pressure, are boiled with 2½ to 3 pounds of alcohol of 80
a glass flask placed in a water-bath till about half a pound of the
d off; the powder is then pressed, and the residue is subjected to the
The press-cake (weighing from 660 to 670 grms.), after being well-
ised, is next macerated for about twelve hours with 3 pts. of cold water;
oved by decantation and pressure; the residue is again treated with 2

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pts. water; the watery extracts are evaporated to a
barium (carbonate of lead would give rise to the
syrup is boiled with 3 or 4 pounds of alcohol of 85 p
is treated in the same manner with 2 pounds of al
are filtered after standing for 24 hours; the alcoho
left to crystallise in shallow dishes. Lastly, the cr
a few days is stirred up to a thin pulp with alcohol
between linen cloths, and the nearly white cake th
from alcohol of 84 to 90 per cent. Two pounds of
the average, from 5 to 6 grms. of myronate of pota
mother-liquors may be used for the preparation of c
This mode of preparation, and the similar method
do not differ in any essential particular from that

Myronic acid may be obtained from the potassiu
solutions of 100 pts. of this salt and 38 pts. tartari
tent, and extracting the myronic acid with alcohol; o
salt into a barium-salt, and precipitating its aqueo
tity of sulphuric acid. The colourless aqueous acid
an inodorous, bitter and sour, uncrystallisable syr
dissolves in *alcohol*, but is not perceptibly soluble i
strongly heated, yielding various volatile products.
some time, gives off sulphydric acid. With an aque
phocyanate of allyl. (Bussy.)

The myronates are inodorous and likewise
aqueous myrosin. They are all, even the barium-, le
The ammonium-, barium-, potassium- and sodium-

Myronate of Barium, $C^{10}H^{18}BáNS^2O^{10}$, obta
the potassium-salt with tartaric acid and absolute
aqueous myronic acid with carbonate of barium,
which become opaque and milk-white on exposure
heat, giving off oil of mustard and leaving sulphate

Myronate of Potassium, $C^{10}H^{18}KNS^2O^{10}$,
needles grouped like crystals of wavellite; from wate
of rhombic character. It has a cooling bitter taste,
difficulty in dilute alcohol, is nearly insoluble in al
in ether, benzene, and chloroform. The solutions ar
light. The salt is anhydrous and contains the elem
acid sulphate of potassium, into which products it

$$C^{10}H^{18}KNS^2O^{10} = C^4H^5NS + C$$

The dilute aqueous solution mixed with *myrosin*, o
extract of white mustard, becomes turbid in a short
and giving off the odour of oil of mustard. The so
and dextroglucose; the turbidity arises from free s
ganic substance probably formed from the myrosin
similar results of the decomposition of myronate of
Ludwig and Lange, who however assign to it the in
Myronate of potassium is not decomposed by emuls
or by yeast or saliva.

When myronate of potassium is heated to boiling
water, a precipitate of barytic sulphate is formed, wi
The same precipitate, containing half the sulphur in
when the solution of the potassium-salt previously
baryta-water in the cold; but in this case, the c
remain in the solution in the form of a compound p
separable into mustard-oil and glucose.

Potash-ley of specific gravity 1·28, mixed with dr
spontaneously heated to the boiling point, giving of
of allyl, and ammonium.

Myronate of potassium, treated with *zinc* and *h*
off sulphydric acid, which is likewise evolved, tho
hydrochloric acid alone. The solution then contain
half the sulphur in the form of sulphuric acid.

A solution of myronate of potassium, mixed with
yellowish-white precipitate, easily soluble in acetic a
the elements of myronic acid. *Mercurous nitrate* fo
which is decomposed by heat, with formation of mus

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When a moderately concentrated aqueous solution of myronate of potassium is mixed with *nitrate of silver*, nitric acid is set free, and a white curdy precipitate is formed, containing, when dried over oil of vitriol, the elements of sulphocyanate of allyl and sulphate of silver ($C^6H^5Ag^2NS^2O^4 = C^6H^5NS.Ag^2SO^4$). Its formation is represented by the equation,

$$C^{10}H^{18}KNS^2O^{10} + 2AgNO^3 = C^6H^5Ag^2NS^2O^4 + C^6H^{12}O^6 + KNO^3 + HNO^3.$$

This silver-compound, heated either alone or with water, is resolved into sulphocyanate of allyl, sulphate of silver and sulphide of silver; it is also decomposed, with evolution of mustard-oil, by *chloride* or *sulphide of barium*, or by *zinc*. When it is treated with *hydrochloric acid*, the liquid filtered from the chloride of silver contains half the sulphur in the form of sulphuric acid, but no sulphydric acid or sulphocyanate of allyl is produced. The silver-compound, suspended in a large quantity of water, is decomposed by *sulphydric acid*, with formation of a precipitate of sulphur and sulphide of silver; and the strongly acid filtrate, which contains half the original quantity of sulphur in the form of sulphuric acid, yields by repeated distillation an oily layer, consisting of cyanide of allyl, $C^3H^5.CN$:

$$C^6H^5Ag^2NS^2O^4 + H^2S = C^4H^5N + Ag^2S + S + H^2SO^4.$$

The cyanide of allyl thus produced differs considerably in its properties from that which Lieke obtained by the action of cyanide of silver on iodide of allyl (ii. 203). It is a colourless neutral oil of agreeably alliaceous odour and burning aromatic taste. Specific gravity = 0·8389 at 12·8°. Vapour-density = 2·32 (calc. 2·31); boiling point 116° (corrected 118·3°). Heated with strong potash-ley in a sealed tube, it is resolved into ammonia and crotonic acid, $C^4H^6O^2$. (Will and Körner.)

MYROSIN. An emulsion-like substance, of the albuminous or protein class, contained in the seeds of black and white mustard, and possessing the property of decomposing the myronate of potassium contained in the former, with production of sulphocyanate of allyl or volatile oil of mustard. It is likewise contained in the seeds of other cruciferous plants, viz. *Raphanus sativus*, *Brassica Napus*, *Br. oleracea* and *Br. campestris*, *Alliaria officinalis*, *Cheiranthus Cheiri*, *Draba verna*, *Cardamine pratensis*, *C. amara* and *Thlaspi arvense*. (Lepage.)

To prepare it, pulverised white mustard is exhausted with cold water; the filtrate evaporated to a syrup at a temperature below 40°; the syrup precipitated by a moderate quantity of alcohol; the precipitate dissolved in water after the alcohol has been poured off; and the solution evaporated to dryness at a temperature below 40°.

Myrosin, as thus obtained, resembles other protein-compounds. When incinerated, it leaves sulphate of calcium.

In the state of aqueous solution, it is coagulated by heat and also by alcohol, and loses its power of eliminating oil of mustard from myronic acid, but recovers this power after immersion in water for twenty-four to thirty-six hours. It does not eliminate hydrocyanic acid from amygdalin.

The aqueous solution of myrosin is transparent, colourless, and gummy, and froths when agitated. (Bussy, J. Pharm. xxvi. 44; Winckler, Jahrb. pr. Pharm. iii. 93.)

MYROXOCARPIN. (Stenhouse, Ann. Ch. Pharm. lxxviii. 306.)—A crystallisable substance extracted from white Peru balsam (i. 496). On digesting this balsam with alcohol of ordinary strength, a great part dissolves, and the solution gradually deposits large crystals of myroxocarpin mixed with resin; they may be purified by recrystallisation with aid of animal charcoal.

Myroxocarpin crystallises in large thin, colourless, shining prisms, often an inch long. According to a determination by Miller, they belong to the trimetric system, the ratio of the principal axis, macrodiagonal and brachydiagonal, for the primary octahedron P, being as 1 : 0·9363 : 0·7553. Observed combination $\infty P . oP . \infty\breve{P}\infty . \breve{P}\infty . 2\breve{P}\infty . \bar{P}\infty . 2\bar{P}\infty$. Angle $\infty P : \infty P = 102° 12'$; $\bar{P}\infty : oP = 127° 4'$; $2\bar{P}\infty : oP = 110° 41'$; $\breve{P}\infty : oP = 133° 7'$; $2\breve{P}\infty : oP = 115° 5'$. The crystals are hard and brittle, insoluble in water, very soluble in hot alcohol and ether, tasteless, and neutral to test-papers. They give by analysis 77·18 per cent. carbon, and 9·5 hydrogen, which may be represented by the formula $C^{18}H^{35}O^8$, or $C^{18}H^{70}O^8$.

Myroxocarpin melts at 115° to a transparent glass, which does not crystallise on cooling, but if redissolved in boiling alcohol, is again deposited in the crystalline form. Heated considerably above its melting point, it yields a sublimate, together with much acetic acid, and an uncrystallisable resin.

It does not unite with *acids*, or with *alkalis*, and is not attacked by boiling *potash-ley*.

Hot *nitric acid* slowly converts it into oxalic acid and an uncrystallisable resin. *Chlorine*, with aid of heat, likewise converts it into an amorphous resin.

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MYROXYLIC ACID. The name given b
decomposition of cinnamein (i. 981) by alcoholic
acid.

MYROXYLON PEREIRAE. The tree wh
bark of this tree there exudes a gum-resin, which,
Trans. [2] v. 248), contains 77·4 per cent. resin, 17
fibre, and 4 water, together with volatile oil. It
solution reddens litmus slightly. This gum-resin
nature from the balsam obtained from the fruit of t

MYRRH. A gum-resin which exudes from A
thaceous shrub growing in Arabia and Abyssinia.
various size, reddish colour, and irregular shape, h
on the surface, semi-transparent, fragile, shining wi
surface. It has a rough bitter taste, and a strong,
The following are analyses of myrrh:

Resin	23·0	27·8
Essential oil . . .	2·5	2·6
Gum	46·0	54·4
Mucilage		
Foreign matters (potassium-salts of sulphuric, benzoic, malic, acetic acid), &c.		1·4 (f
Water and impurities . . .		1·6

An alcoholic solution of myrrh concentrated by d
resin, like turpentine, soluble in ether, slightly solul
a violet-red colour to nitric and acetic acid.
Another resin, called myrrhin, remains dissolv
tained by evaporation. It has the odour of myrrh,
soluble in ether. Heated for some hours to 168°, it
(acetic or formic acid?), and leaves a red-brown
taste or smell, soluble in alcohol and ether, insolubl
in boiling potash. This product imparts a viol
dissolves in sulphuric acid with red-brown colour
cent. carbon, 8·06 hydrogen, and 17·16 oxygen. (
The essential oil (myrrhol) obtained by disti
with water, is thick, yellowish, has a rough taste ar
turns brown in contact with the air, dissolves in al
by water from its alcoholic solution in the form of a
It contains, according to Ruikholdt, 79·61 per cent
oxygen.
Gladstone (Chem. Soc. J. xvii. 11) has exam
directly distilling myrrh with water. It was ver
colour; and began to boil at about 266°, giving an o
and retained its greenish colour, and strong smell of
Specific gravity = 1·0189 at 15·5°. Index of refra
D, 1·5278; H, 1·5472. Rotatory power = — 136.

MYRRHIN and **MYRRHOL.** See the last a

MYRTLE. *Myrtus communis.*—The berries
Riegel (Pharm. Centr. 1850, p. 319), chlorophyl
(occurring also in the leaves), a fixed oil, tannin, su
humous substances, and small quantities of potash a
Of a specimen of the volatile oil of myrtle, examin
fourths distilled over between 160° and 176°, leavi
evolved sulphydric acid. The rectified distillate sme
composition of a hydrocarbon isomeric with oil of t
= 0·8511 at 15·5°. Index of refraction at 14°, for
for H, 1·4879. Specific rotatory power = + 21°.

MYSORIN. Anhydrous cupric ortho-carbonate
i. 783).

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